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DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
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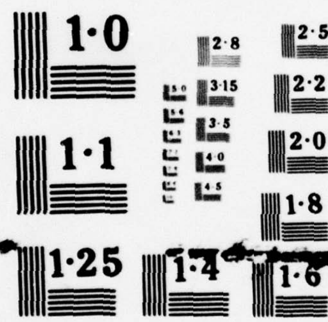
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DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE EQUIPMENT

Volume I: Analysis

U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge MA 02142

FEBRUARY 1979

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
Office of Research and Development
Washington DC 20590

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16. Abstract

This report presents ~~the~~ results of a study to examine the siting and equipment requirements that would have to be met for the U.S. Coast Guard to provide an adequate response within six hours for spills of up to 100,000 tons (28,000,000 gals.) of oil in U.S. waters. A data base of spills over 50,000 gallons in U.S. waters has been compiled from the Pollution Incident Reporting System and National Response Center files of the USCG. Spill rates are derived and applied for the U.S. as a whole and for four major sub-areas. A set of baseline pollution response equipment is adopted, and several equipment site configurations covering the U.S. are evaluated on the basis of six-hour coverage, historic spills encompassed and spill potential. Relative levels of equipment capability for the sites are derived from a simple optimization model.

These relative levels are converted to specific equipment requirements on the basis of reasonable forecasts of oil movements in U.S. coastal waters, including oceanic tankers, coastal tank vessels, deepwater ports, and outer continental shelf production. ~~The~~ additional needs of the U.S. Coast Guard are estimated by subtracting the response capacity of equipment available from other response organizations.

Finally, worldwide experience of oil spills larger than 1,000,000 gallons is also examined for ~~the decade~~ 1968-1978, and three massive spill scenarios are presented for the U.S. Atlantic and Pacific coasts. Corresponding response scenarios are evaluated, and site locations, equipment levels and logistic requirements are re-examined. System adjustments are noted, where indicated.

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PREFACE

This report is one of a series of studies conducted by the United States Coast Guard in support of the Presidential initiative of March 1977, concerning the ability of the United States to respond to the threat of larger oil spills in U.S. waters. The study was directed by the U.S. Coast Guard Office of Research and Development and Office of Marine Environment and Systems. The authors wish to acknowledge with thanks the expert and indispensible assistance rendered by these Offices throughout the project, and in particular that of Cdr. J.T. Leigh/GDOE, Cdr. J.L. Valenti/GWEP, Lt. R.V. Harding/GDSA and Lt. G.D. Marsh/GDOE. They are also indebted to numerous Coast Guard personnel, both at headquarters and in the field organizations, who enthusiastically provided data, advice and information.

The report is in two volumes. The first volume presents the main analysis, while the second contains the technical Appendixes.

The Department of Transportation's report to the President on the entire study effort is entitled "A Plan for Implementing Presidential Initiatives Concerning Oil Pollution Response," and may be ordered through the National Technical Information Service, Springfield, Virginia, 22161, as Report No. AD-A067163. A supplemental report is also available with the NTIS number, AD-A067076.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

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1. INTRODUCTION

The Oil Pollution Response System study was undertaken by the U.S. Coast Guard in response to a White House policy statement communicated to the Congress on March 18, 1977. The President was moved to make this statement after a number of tanker accidents along the coasts of the United States, including the SANSINENA and the ARGO MERCHANT incidents in December of 1976.

In these and lesser pollution incidents, the Coast Guard may be required to assume responsibility for removing or arranging for the removal of any oil discharged into the navigable waters of the United States. The authority to exercise this responsibility is vested by Congress in the President[1] and delegated by him to the Coast Guard[2].

The Public Law which establishes the Executive authority in this area is the amended Federal Water Pollution Control Act of 1972. In Section 311 of the Act (86 STAT 863), Congress has declared that "it is the policy of the United States that there should be no discharge of oil or hazardous substances into or upon the navigable waters of the United States..." Whenever such discharges do, nevertheless, occur in the coastal regions, whether intentionally or accidentally, the responsible officer of the Coast Guard (the On-Scene Coordinator) has the authority to act if he determines that such action is necessary to limit and/or remove the discharge. In carrying out his responsibilities the OSC is assisted by the response mechanism set up by the National Contingency Plan, which includes the National Strike Force.[3]

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[1] Public Law 92-500, The Federal Water Pollution Control Act Amendments of 1972

[2] Executive Order No. 11735, August 3, 1973.

[3] Federal Register, Vol. 40, No.28, Part II, Feb. 10, 1975.

The stated objectives of the National Contingency Plan are "to provide for efficient, coordinated and effective action to minimize damage from oil......discharges, including containment, dispersal, and removal." Among other provisions, the Plan sets up a response organization and defines the actions required at each phase of the response operation. It also provides for the establishment of the National Strike Force to be formed around three Strike Teams maintained by the Coast Guard at bases on the East, West, and Gulf Coasts. These Strike Teams consist of about twenty-four (24) trained personnel, with specialized oil transfer, containment, and recovery equipment, prepared and available on short notice to provide needed services at the request of the On-Scene Coordinator. They are skilled in pollution response techniques and have knowledge and experience of damage control and diving. Current plans call for the addition of towable storage bags and additional open water recovery systems to the Strike Force inventory in the near future.

This then is the context within which, on March 18, 1977, the President of the U.S. directed the Coast Guard, the Environmental Protection Agency and other responsible Federal agencies to upgrade their ability to respond to large spills of oil. For the Coast Guard the immediate objectives are to investigate the feasibility of providing for an adequate response to major pollution incidents within six hours, and of maintaining sufficient equipment in its inventory to deal with a spill of up to 100,000 tons of oil.

1.1 STUDY GOAL

In response to the Presidential initiative of March 18, 1977, the Coast Guard instituted a series of studies designed to determine how best to upgrade its ability to respond to large spills of oil in open waters or under extreme conditions of weather and temperature. The study that was assigned to the Transportation Systems Center consists of two parts:

a. An equipment siting study;

b. A study of the response problems associated with a massive spill.

It has been pointed out in numerous places and on numerous occasions that more and larger oil spills are an inevitable consequence of the transport and transfer of ever increasing volumes of oil, and oil products. Preventive measures and prudent procedures can limit but not eliminate accidental spills, which are most often small and of minor consequence but occasionally massive, with major impact on the environment and on nearby communities.

It has also been pointed out that in many respects oil spills resemble fires. Both are potentially disastrous events that may happen anywhere and at any time, although it may be possible through careful study to identify the circumstances that increase the risk. Furthermore, the response organizations must maintain themselves in a continuous state of readiness and must always be prepared to act on an emergency basis. In the event, their first duty is to prevent the loss of life; following that, to limit the environmental impact.

When no lives are at stake, the principal concerns become to stop the leak and contain the damage (put out the fire and prevent its further spread). To perform this function efficiently and effectively requires specialized equipment and trained personnel. These are the resources that must be provided by the Coast Guard when large spills occur in open waters where private efforts may be of no avail. The amount and disposition of these resources is the subject of this study.

1.2 PROBLEM DESCRIPTION

Executive Order 11735 requires the Coast Guard to coordinate and direct pollution control efforts at the scene of an actual or potential oil spill on coastal waters of the United States. In most instances, especially in protected waters, this effort is limited to overseeing the actions of the party responsible for the spill or of his representatives. If the predesignated On-Scene

Coordinator (OSC) determines, however, that containment and removal of the oil is not being done properly, he must himself take the necessary actions to accomplish those objectives.

If Federal action is required, the OSC makes use of the equipment and personnel of commercial contractors to the maximum possible extent. Incidents do occur, however, particularly in open waters, when these private resources are inadequate for the task. At such times the resources available tc the OSC can be augmented by the National Strike Force with its complement of trained personnel and its inventory of open water response equipment. It is apparent that this emergency resource (the NSF), even with the augmentation presently planned for it, is not sufficient to meet the Presidential goals for responding to the large spills in open waters that are increasingly likely to happen in the next ten to twenty years.

Given the perceived need for more high-capacity, open water response equipment, more widely deployed, the Coast Guard is faced with a multi-faceted problem some of whose dimensions are listed below:

How much open water response equipment is needed to deal effectively with the size-range and frequency of spills likely to be encountered?

b. Where should the required equipment be deployed in order to meet the President's six-hour response criterion?

c. How effectively could this equipment deal with a 100,000 ton* (28,000,000 gallon) spill, if one were to occur?

c. What will be the cost in dollars and manpower to procure, establish, and maintain the necessary equipment and put it to effective use when and where the need arises?

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*A spill of this magnitude is equal to the Torrey Canyon, to one-half of the Amoco Cadiz, or to 4 times the Argo Merchant.

In order to arrive at reasonable answers to these and other questions, certain guidelines and assumptions have been agreed to and are presented in the next section of this Report.

1.3 ASSUMPTIONS AND GUIDELINES FOR THE OIL POLLUTION RESPONSE SYSTEMS STUDY

a. The regions of interest in the equipment siting study are the coasts, harbors, and adjacent waters of the contiguous United States, plus Puerto Rico, the Great Lakes, and oceanic waters out to 50 miles* from shore. In this context, the adjacent waters are defined to include rivers, bays and estuaries from the coast up to the agreed upon boundary that separates the area of responsibility of the Coast Guard from that of the Environmental Protection Agency.

b. The incidents to be studied are those involving actual and potential spills of 50,000 gallons or more of oil or oil products. Data will also be collected for spill magnitudes between 10,000 and 50,000 gallons.

c. For the purposes of this study, a response requirement for major spills, up to 100,000 tons (28×10^6 gallons) in magnitude, is to be able to make an adequate response within six hours.

d. An adequate six-hour response to a spill of 50,000 gallons or more is assumed to include the following features:

1. The On-Scene Coordinator has arrived at the response center.
2. The OSC has assessed the situation and has established an initial operating plan.
3. Lines of communication have been established.
4. The OSC has established control of the equipment he estimates will be needed.
5. Coast Guard response personnel have been briefed and dispatched in accordance with OSC orders.
6. Coast Guard response equipment requested by the OSC has arrived at the designated debarkation point.

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*Recent law extends some of the U.S. Coast Guard's responsibilities to 200 miles from shore.

e. The six-hour response time begins when the office of the OSC has been advised that a response is necessary.

f. Although aircraft may be used whenever it is advantageous to do so, the initial six-hour response requirement shall not depend on the availability of aircraft.

g. To the extent permitted by available resources, a twelve-hour response, using available aircraft, will also be analyzed.

h. Each geographic area or zone should have available sufficient equipment to deal with one incident in open water within its zone involving 100,000 gallons of oil.

i. In addition to the 100,000 gallon open water response capability, the Coast Guard intends to establish and maintain the marginal resources needed for protection against the projected massive spill threat.

j. The Coast Gaurd does not intend to acquire a self-contained capability to respond to all spills without recourse to alternative resources.

k. Wherever possible, Coast Guard resources will be deployed with the intention of supplementing or augmenting alternative resources.

l. Inventories of response equipment will be obtained or compiled by the Coast Guard. They will include equipment for the containment, cleanup, transfer, storage, and disposal of spilled oil as well as the numbers and locations of barges, tugs, applicable Coast Guard vesssels, and aircraft. These inventories will cover private contractors, oil companies, oil company cooperatives, the Coast Guard, and other Government agencies.

m. The assumptions that will be made for the Site Selection Study are:

1. Oil spills that occur in protected water when the wave heights do not exceed two feet (sea state 2, or smaller) normally can be cleaned up without the need for Coast Guard equipment.
2. Specialized Coast Guard equipment will be needed whenever the wave heights are between two and five feet (sea state 3).

3. An effective response is beyond the present state-of-the-art whenever wave heights exceed five feet (sea state 4, or greater).

1.4 THE SCOPE OF THIS REPORT

This final report presents the results of work completed on the two principal tasks of this project: the Equipment Siting Study and the Massive Spill Study. An equipment status study was the subject of a separate working paper issued in April 1978. Applicable portions of that study are included in Section 6 of this report.

The Equipment Siting Study has been based primarily on historical data relating to petroleum throughput and concomitant oil spills. As one might expect, the number of spills increases in proportion to the product flow. A more detailed analysis of the statistics of spills greater than 50,000 gallons enables one to calculate expected spill distributions for each of several high-risk areas and to project spill probabilities cautiously into the future. The effects of future deepwater ports, of offshore drilling, and of shifts in the domestic/import oil trade, including transient tankers and lightering, have also been examined.

On the basis of the projected spill potential, it has been possible to produce and evaluate several equipment site configurations which satisfy the six-hour response requirement using land and/or sea transport. The configurations, together with suitable assumptions about the numbers of spills to be expected in specific regions and the availability of all the elements of the Coast Guard baseline response system, provide the grounds for estimating desirable equipment levels at each site in a few selected configurations.

Although spills in excess of 50,000 gallons are not uncommon in U.S. coastal waters, in the four year period, 1974-1977, only one accidental spill of this magnitude occurred in the 3 mile to 50 mile zone - the Argo Merchant in Dec. 1976. This incident is in the class of Massive Spills which is the second subject of this

report. In order to increase the information base for the massive spill analysis, data were collected on historic massive spills world-wide from a variety of sources.* Incidents that occurred within 50 miles of any coastline (about 2 or 3 per year) were used as the basis for estimating the potential for future massive spills in U.S. waters and for the postulation of likely spill and response scenarios.

*Among the sources consulted were Lloyd's Weekly Casualty List; the Tanker Advisory Center, Inc. and the Center for Short-lived Phenomena.

2. TECHNICAL APPROACH

The overall project objectives may be summarized in the answers to four questions:

a. What probable spills must the U. S. Coast Guard be prepared to combat in the next decade?

b. What types of equipment are needed?

c. How much of it is needed?

d. Where should it be located?

A fifth question may be added, the answer to which follows from the answers to the first four: What personnel, maintenance, communications and logistic support are required.

2.1 OUTLINE OF TASKS

The first question must be answered at least partly before the remaining ones can be attacked. An estimate of the number, location, size, and type of spills to be dealt with is fundamental to assessing what types or quantities of equipment are required, or where it should be placed. Hence, the Geographic Spill Potential Study, described in Section 3, is the starting point in the technical approach. The sequence of investigation, starting with the Geographic Spill Potential Study,is as follows:

Geographic Spill Potential

The projection of spills to be dealt with in the next decade proceeds from a study of historic spills in the recent past. Data have been gathered for the 1974-1977 period on actual and potential spills in the United States. The national and regional spill rates can be related to oil throughput, historically, and projections made of the number of spills as a function of oil traffic. By adding considerations of future deep-water ports, offshore drilling and import/domestic oil trade, these estimates can be improved to cover the 1980-1990 decade.

Massive Spill Potential

In addition to the spills that may be projected on the basis of recent history, the potential for spills in the 1980-1990 decade of the order of 100,000 tons must be assessed. Although the probabilities for spills may be difficult to assess, an estimate must be made of what locations are likely to experience massive spills, if massive spills do occur. The estimates must be made on the basis of projected traffic patterns, possible deep-water port locations and OCS development, as well as historic world wide data on massive spills.

Environmental Data

Weather conditions at the scene of the spill can reduce the effectiveness of the recovery or offloading equipment, restrict the types of equipment that may be employed and, in fact, determine whether any effective action can be taken at all. Weather data on sea height, current, wind speed and water temperature in the various parts of the study area will be gathered for use in assessing the effectiveness of current equipment.

Equipment Capabilities

It is necessary next to estimate the rates and total quantities achievable for offloading and for recovery by different equipments, currently available to the U.S. Coast Guard, for given environmental conditions and petroleum types. This will be done for a set of baseline equipment, specified by the U.S. Coast Guard. In addition, surveys of available non-U.S. Coast Guard equipment will be used to determine what capability is available to supplement USCG equipment.

Logistic Assumptions

In order to determine the response range (i.e., the distance from a storage site that the equipment may be transported in the specified response time), an investigation will be carried out of vehicle carrying capacities, ranges, speeds, and other characteristics. All the time intervals involved will be analyzed, from receipt of the OSC (On-Scene Coordinator) request for assistance to the arrival of the equipment at the debarkation point, in order to arrive at the response range.

Site Selection

Site locations will be selected so that (1) as many potential debarkation points as possible lie within the response range of some site, and (2) the average time required to respond to a spill is a practical minimum. Sites will be selected to achieve the first objective by a geometric/geographical approach, and to achieve the second objective by ordering the areas of oil movement by their spill potential (i.e., expected number of spills per year). Several site configurations will be tried and measures of effectiveness applied to compare them. These measures will include (1) the number of potential debarkation points not covered by some site, (2) the number of debarkation points covered by two or more sites, (3) the number of past actual and potential oil spills with debarkation points outside of coverage, (4) the amount of oil movement occurring at ports that are also equipment sites, and (5) the average time to respond to a spill. Based on these measures, one or more site arrangements will be selected.

Equipment Levels

Relative equipment levels at the sites will be determined by considering the expected number of oil spills in the regions covered by the sites, and the expected distribution of spill volumes. Absolute levels of equipment will be related to net effectiveness, using the offloading and recovery rates and capacity derived in the equipment capabilities assessment.

Sheltered Water Coverage

Although open water spills present the most demanding pollution response problems for the Coast Guard, the numerous spills that occur in sheltered waters, or under moderate conditions in open water, are also of concern. Not all such spills are small; many occur in currents that equal or exceed present containment capabilities. The above sequence of tasks provides a basis for selecting equipment site locations, relative and absolute equipment levels, and equipment types, keyed primarily to open water spills in difficult circumstances. These selections will be extended to assure adequate coverage of spills in sheltered waters, from the points of view of site location, equipment type, and equipment quantity.

Massive Spill Coverage

The upper extreme of the spill volume distribution is of particular concern because of the potential for serious ecological damage and public reaction. Therefore, the site locations, equipment types and equipment levels resulting from the above sequence of tasks will be analyzed further for effectiveness in responding to massive spills. This will be done by postulating a set of possible massive spills and examining the sequence of response actions likely to occur for each. The arrival sequence of equipment and personnel at the debarkation point will be examined as a function of time. Adjustments in location, type, and quantity of equipment will be made.

2.2 REMARKS

The sequence of tasks outlined above is intended to accomplish the two general tasks mentioned in Section 1:

a. Equipment Siting Study, and

b. Massive Spill Response.

Advantage will be taken of common information and of subordinate studies in order to achieve this goal.

3. GEOGRAPHIC SPILL POTENTIAL

In this section the geographic spill potential will be developed by examining first the relationship between the historical experience of oil spills and petroleum throughput volumes. Following this, spill threat spectra will be derived based on national and regional (geographic) throughput levels.

3.1 HISTORICAL OIL SPILL DATA BASE

The fundamental assumption in the derivation of probabilities of future oil spill occurrence is that meaningful estimates of spill frequency can be based on past experience. To this end, historical data on oil spills were obtained from reports of and personal contacts with the U.S. Coast Guard (USCG), Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) of the Department of the Interior (DOI), from non-governmental organizations, and from the open literature. Review of the available information revealed the fact that no one source of historical oil spill data was sufficiently extensive to satisfy the information needs of this effort. It thus became necessary to construct an appropriate data base to include all post-1973 spills of 50,000 gallons or more in and around the United States.* The spill size was selected so as to be consistent with earlier studies (References 3-1 and 3-2), and the time period to allow maximum correlation of multiple sources of information on identifiable spills.**

The resultant data base, designated the Major Oil Spill Information System (MOSIS) consists primarily of information available from the following USCG sources, each of which contains some unique data:

*Data was also collected for spills between 10,000 and 50,000 gallons for future consideration.

**1974 is the first year for which both PIRS and NRC data are available.

a. The Pollution Incident Reporting System (PIRS)

b. The National Response Center (NRC) case files

c. The On Scene Coordinator (OSC) Reports.

Supplementary information from other sources, most notably EPA OSC reports and DOI publications, have been included wherever available.

A total of 238 actual and potential oil spills are contained in the MOSIS file, 156 of which are in the immediate study area. The primary information assembled for each spill include the date, location, quantity spilled, quantity in the water, type of petroleum, source of spill and cause, plus an indication of the primary and secondary sources of reported data. Other information of interest such as spill rate, duration, environmental conditions, response procedures, equipments, logistics and costs have not been included due to the sporadic manner in which such factors have been reported for the spills of record. Hopefully, such factors will receive more complete and consistent attention where future spills may occur.

The MOSIS file has been reproduced in its entirety in Appendix A with appropriate explanatory notes.

3.1.1 Data Graphics

A graphic presentation of the data base is shown in Figure 3-1 wherein all actual spills in the MOSIS file have been plotted so as to show spill size and petroleum type (crude, heavy or light)* as

*From the Corps of Engineers Commodity Classification for Waterborne Commerce, the three noted petroleum groups are constituted as follows:

Crude:	1311	crude petroleum
Heavy:	2915	residual fuel oil
	2916	lubricating oils and greases
	2918	asphalt, tar and pitches
Light:	2911	gasoline, including natural gasoline
	2912	jet fuel
	2913	kerosene
	2914	distillate fuel oil
	2917	naptha, mineral spirits, solvents, not elsewhere classified.

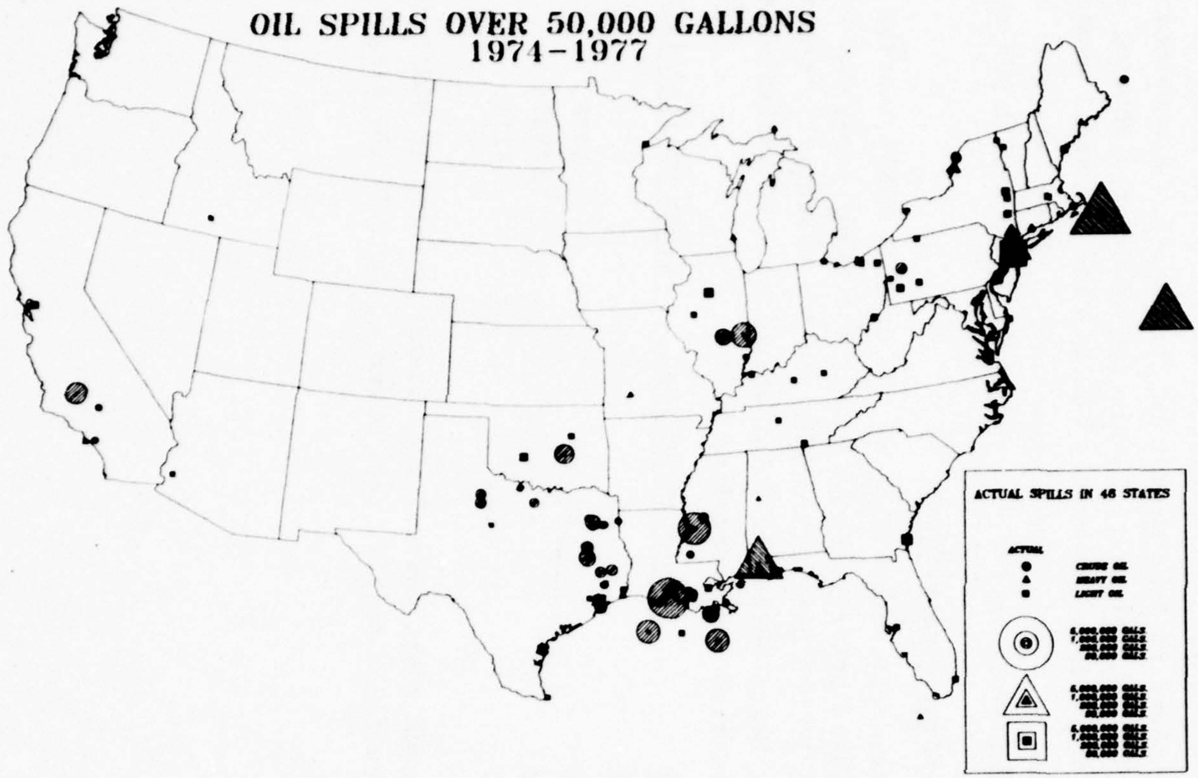

FIGURE 3-1. ACTUAL SPILLS IN 48 UNITED STATES, 1974-1977

well as location as an aid to visualization and analysis. A similar plot, restricted to historic spills in the study area, is shown in Figure 3-2. Potential spills of interest to this study are shown in like manner in Figure 3-3. A combined plot of actual and potential spills in the study area showing location only is included as Figure 3-4 to indicate the areal number density of historic spills and potentials. These data will be used subsequently in the estimation of future spill potential.

3.1.2 General Observations

Certain characteristics of the data in MOSIS, worthy of note, are discussed briefly here. Within the study area, the number of spills of 50,000 gallons or more remains essentially constant on an annual basis while the total amount spilled varies widely. These characteristics are summarized below:

Year	Number of Spills	Amount Spilled (K Gal.)
1974	20	5788
1975	20	8488
1976	22	17981
1977	18	4515

In each year, most of the volume reported in MOSIS resulted from a few large spills. For example, in 1974 the single largest

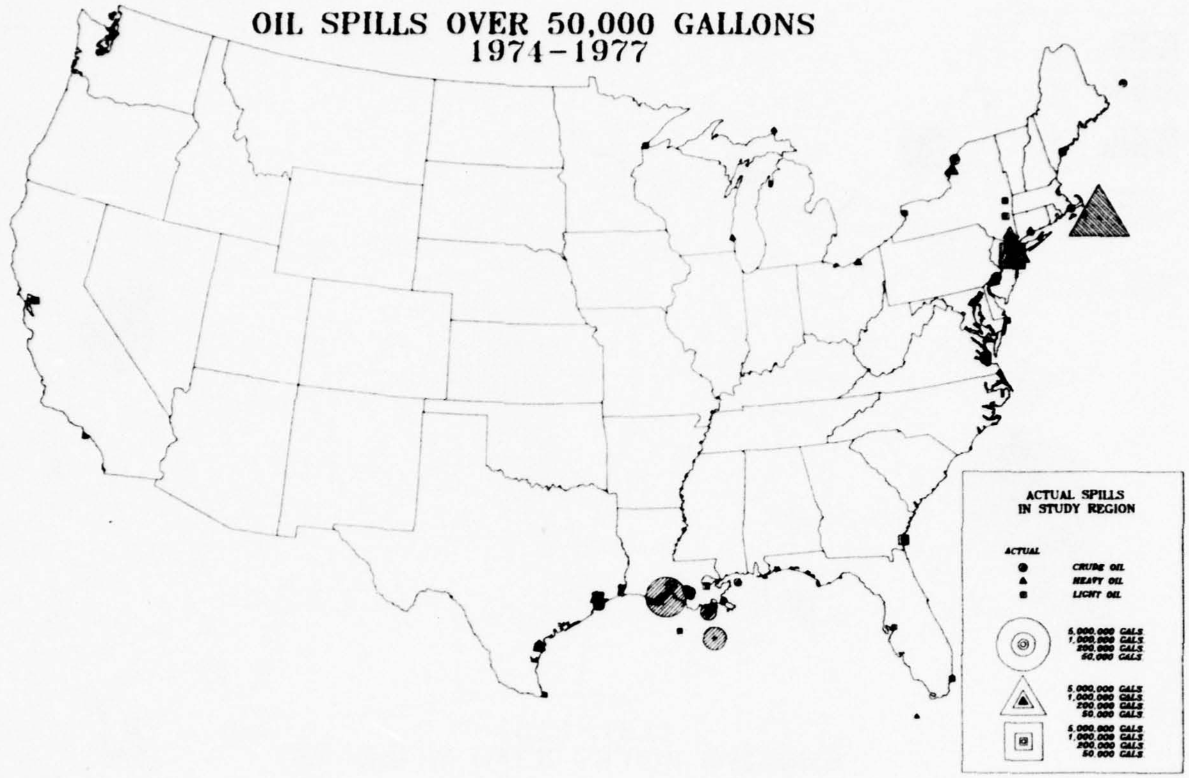

FIGURE 3-2. ACTUAL SPILLS IN STUDY AREA, 1974-1977

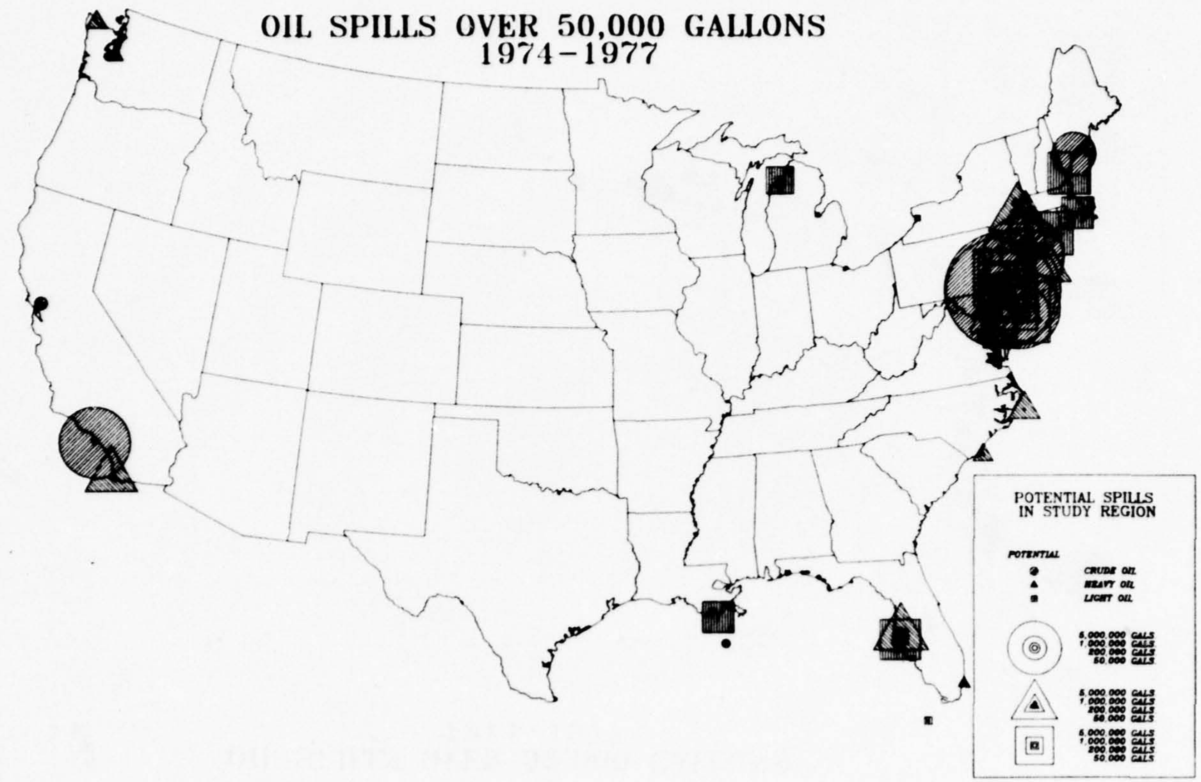

FIGURE 3-3. POTENTIAL SPILLS IN STUDY AREA, 1974-1977

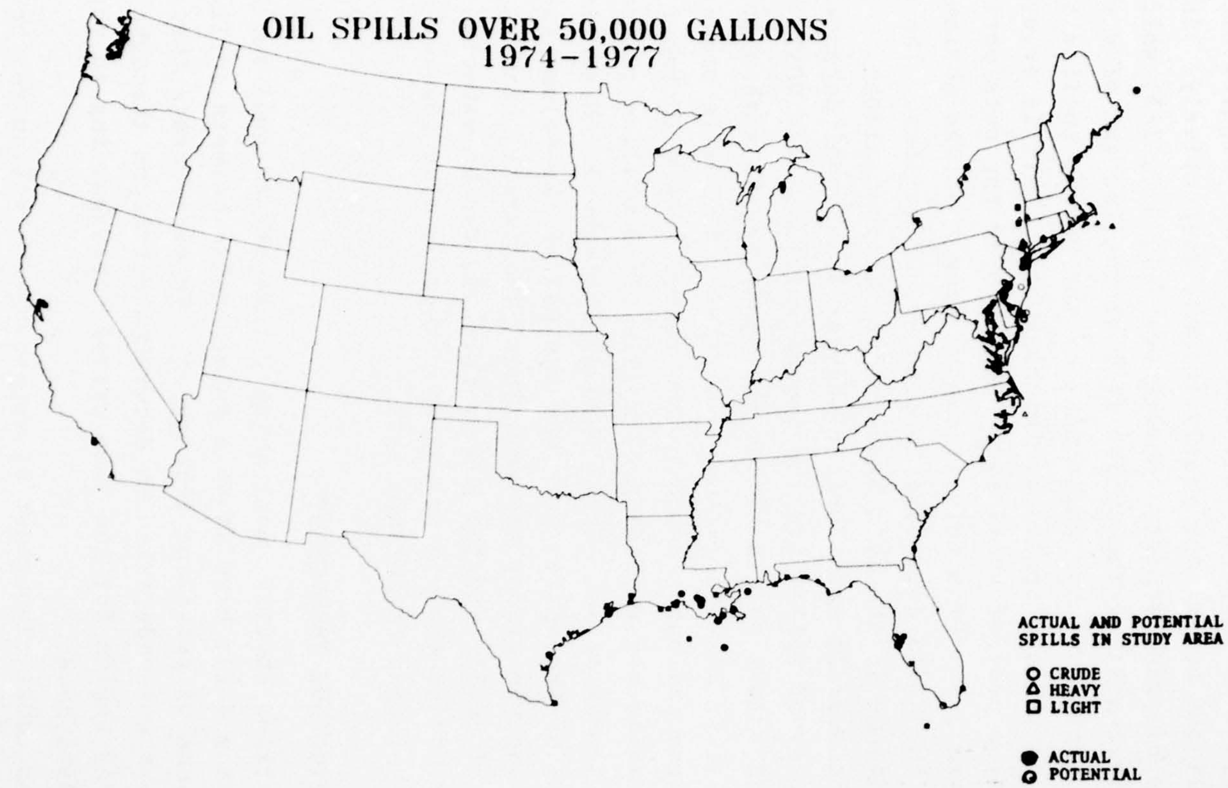

FIGURE 3-4 DISTRIBUTION OF ACTUAL AND POTENTIAL SPILLS IN THE STUDY AREA

spill accounted for 29% of the total volume spilled, in 1975 the figure was 33%, in 1976, 52%, and in 1977, 44%. When the three largest spills in each year are considered, the figures become 60%, 69%, 81% and 60% of the yearly volume, respectively. This is supportive of prior studies (References 3-1, 3-2, 3-3) which have found that most of the spills fall at the low end of a given spectrum of spill volumes while most of the volume spilled is represented by the few spills at the high end. This is evidenced by the cumulative plot of spill size density over the data period as shown in Figure 3-5. From this it can be seen that the median spill volume in the MOSIS data base is some 90,000 gallons. The maximum spill volume in the data base is 7.6 million gallons.

The overall data further suggest a seasonal dependence for both the number of spills and the amount spilled. The MOSIS file contains 80 actual spills within the study region with a total spill volume of 37 million gallons. Of these, 43 spills amounting to 24 million gallons occured in the winter season (October through March) while the remaining 37 spills of 13 million gallons occurred in the summer season (April through September). Historically, then, some 55% of the spills occurred and 65% of the volume was accounted for during the winter season. Thus, the threat, both as to the number of spills and the amount spilled, can be expected to be greater during the winter season. This is also consistent with earlier studies (Reference 3-3).

3.2 PETROLEUM THROUGHPUT

Earlier studies, most notably that of Devanney and Stewart (Reference 3-2), have shown a relationship between spill rate and the volume of petroleum throughput. To corroborate these findings, an effort was undertaken to determine petroleum throughput within the study region for the time period corresponding to that of the MOSIS data base.

The total throughput of waterborne petroleum in the study region was taken from U. S. Army Corps of Engineers data for 1974, 1975, and 1976 (Reference 3-4) and adapted from Federal Energy

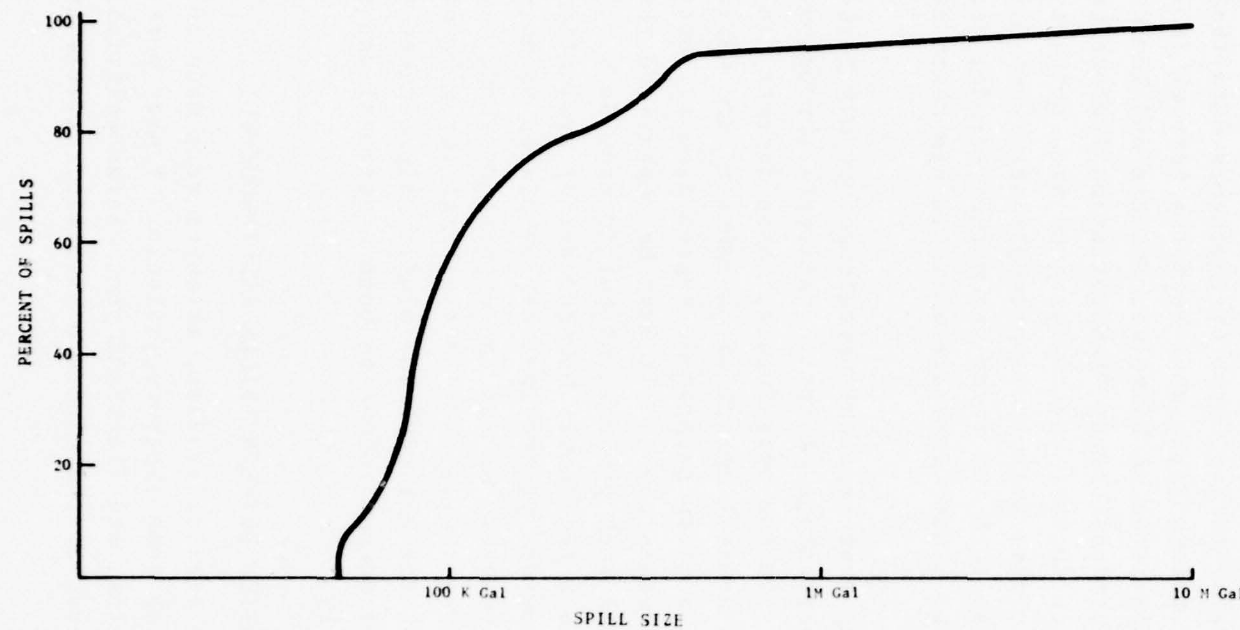

FIGURE 3-5. CUMULATIVE OF SPILL SIZE DENSITY FOR SPILLS $\geq$ 50,000 GAL

Administration data for 1977 (Reference 3-5). This covers the time period for which spill data were compiled in the MOSIS file. These throughput data are summarized in Table 3-1. Graphic representations of waterborne product flow and crude flow, taken from Reference 3-6, are shown in Figures 3-6 and 3-7.

By applying to the Corps of Engineers data the methodologies developed by the Congressional Research Service in its report to the Senate Committee on Commerce, Science and Technology on the subject of National Energy Transportation (Reference 3-6), estimates of regional throughput were determined as a percentage of national throughput. Total petroleum movements were then disaggregated percentagewise into the three categories (crude, heavy and light) noted earlier. These data are shown in pie-chart form in Figure 3-8.

Assuming that regional petroleum-type mix (crude, heavy, and light) and percentage of total (national) throughput will not change significantly in the near future, these factors can be used to estimate the nominal amount of movement of the various types of petroleum in a given geographic region from prcjections of total national movements alone. It must be emphasized that the task here is not to make such projections but to provide a process which is responsive to a reasonably bounded set of projections. Where reasonably bounded projections can be placed on national waterborne petroleum movements, so can the excursions about the nominal regional values. These will provide the basis for a bounded parametric evaluation of the anticipated relationship between spill rate and petroleum throughput volume on both a national and regional (geographic) basis.

3.3 CORRELATION BETWEEN SPILLS AND THROUGHPUT

As with earlier studies, attempts were made to correlate spill frequency with some exposure variable. Tanker port calls, trade route densities, and fleet and port characteristics, among others, were considered as the exposure variable. Little success was met

TABLE 3-1. PETROLEUM THROUGHPUT IN THOUSANDS OF SHORT TONS

Year	Domestic Coastal*	Local**	Import	Total
1974	182838	61473	328725	573036
1975	184397	55375	332473	572245
1976	190416	58565	414542	663523
1977 (Estimated)	195000	60000	520000	775000

*Includes traffic between Great Lakes ports and seacost ports.

**Includes traffic within a single channel of a port and traffic between the several channels of a port. Includes such traffic within Great Lakes ports.

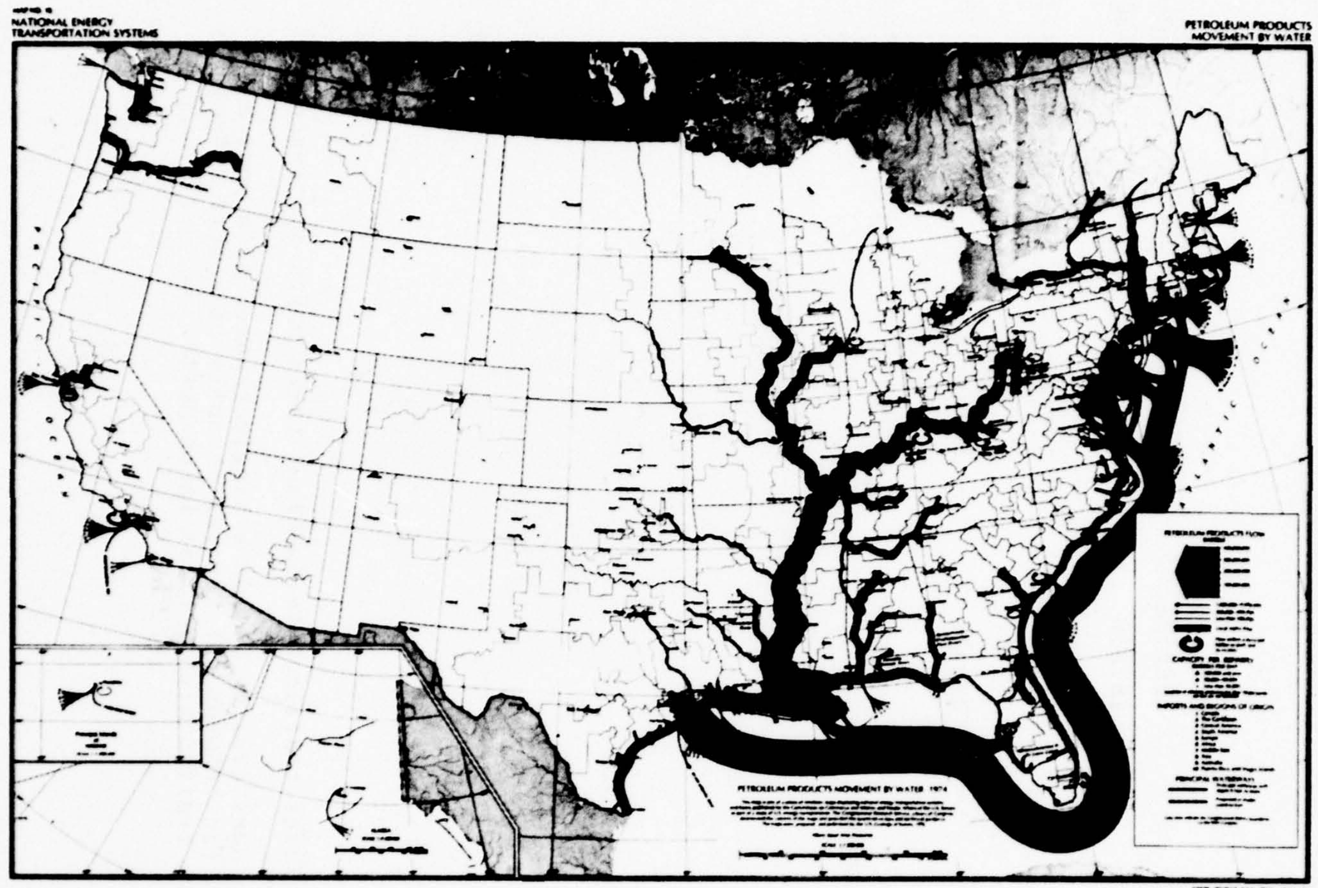

FIGURE 3-6. PETROLEUM PRODUCTS MOVEMENT BY WATER 1974 (FROM REFERENCE 3-6)

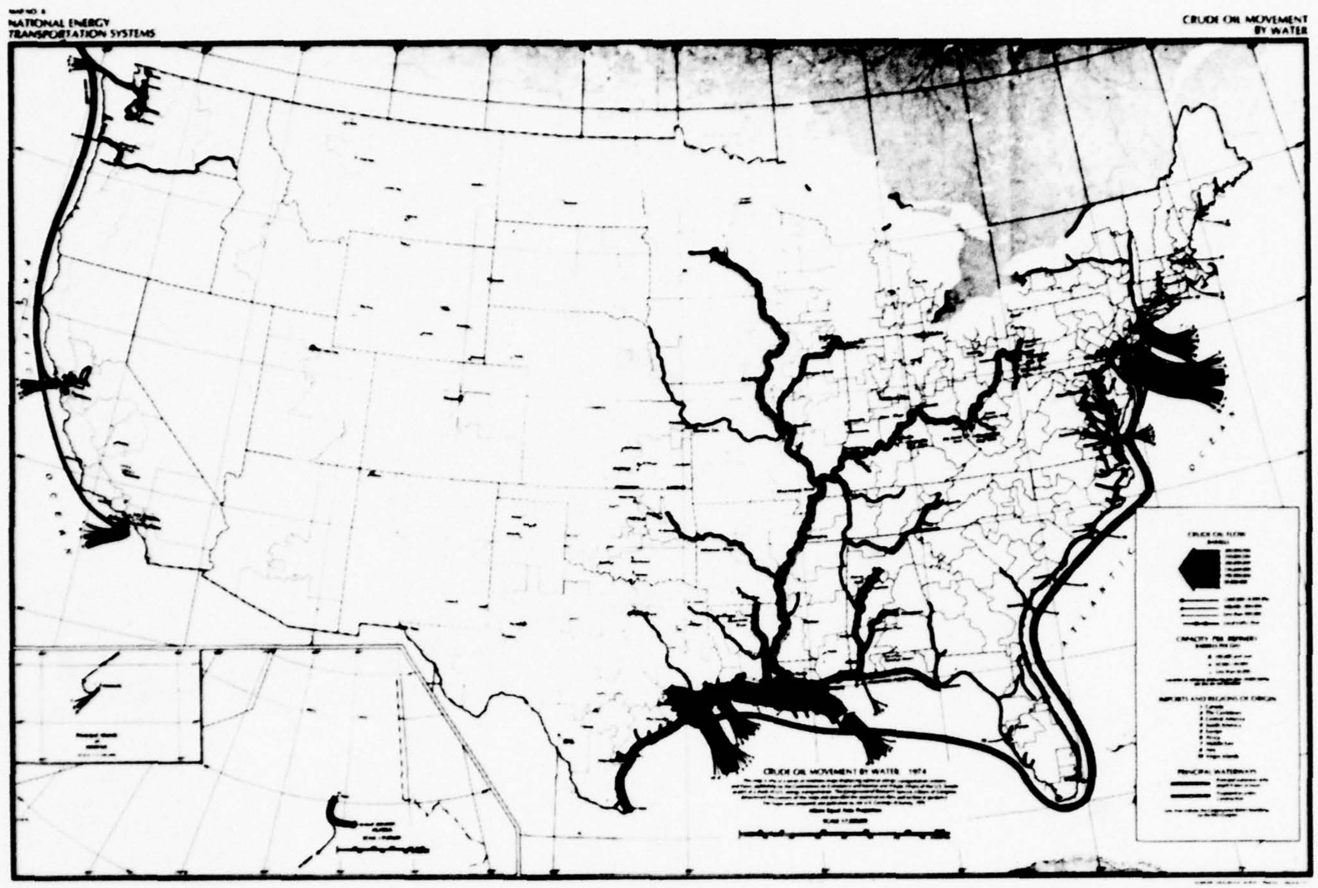

FIGURE 3-7. CRUDE OIL MOVEMENT BY WATER 1974 (FROM REFERENCE 3-6)

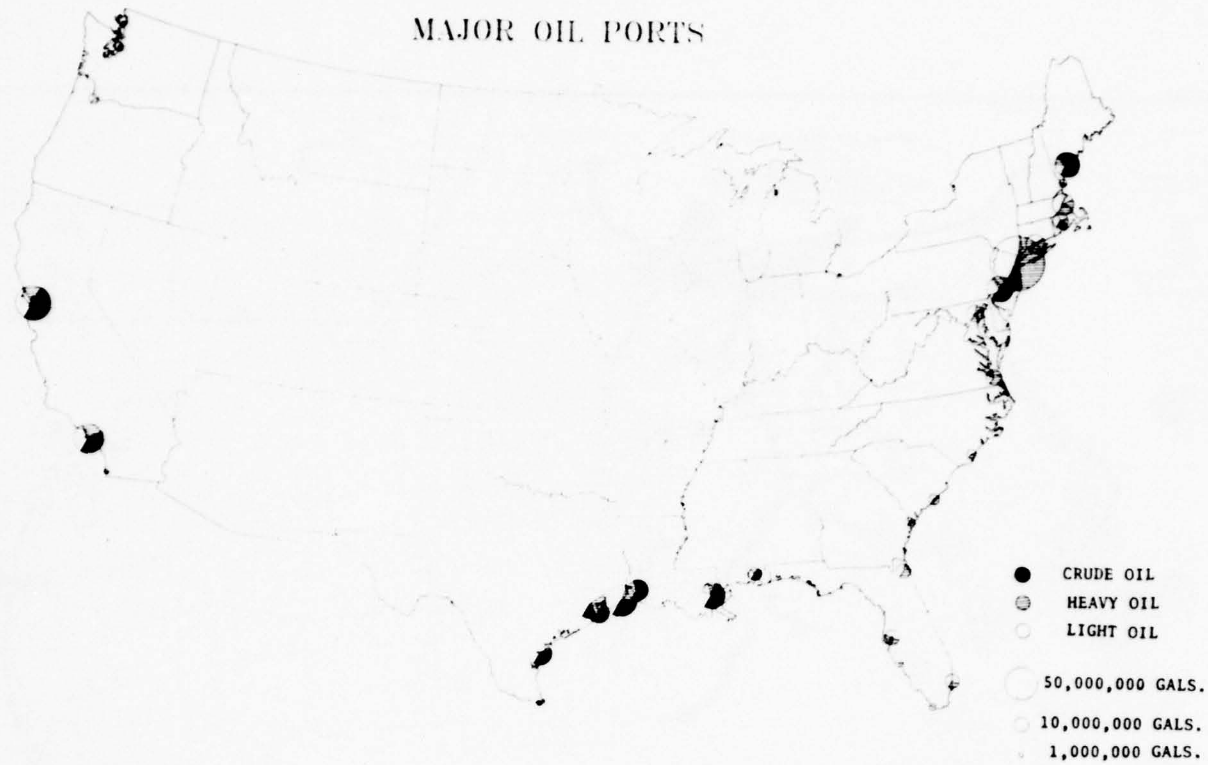

FIGURE 3-8. PETROLEUM THROUGHPUT BY TYPE FOR MAJOR PORTS

in these attempts due primarily to incomplete or inconsistent data or to a determination that the candidate exposure variable was an inappropriate measure. Based on the degree of correlation between the number of spills and petroleum throughput found in other studies (e.g., References 3-1 and 3-2), linear regressions were performed to determine what, if any, degree of correlation exists between the two using the data of Sections 3.1 and 3.2. Regressions were carried out for both the overall study region and for selected geographic areas (regional level) where data permitted for both actual and potential spills.

3.3.1 Actual Spill Data

3.3.1.1 Overall Study Area - The spill and petroleum throughput data for actual spills within the overall study region are summarized below:

Year	Actual Spills	Throughput(MT)
1974	20	573.0
1975	20	572.2
1976	22	663.5
1977 (E)	18	775.0

where MT represent millions of short tons. The least squares fit to the cumulative of these data is:

$$n = 2.057 + 0.0314V$$

where n is the number of spills and V the throughout volume in MT. Figure 3-9 shows this relationship graphically. This relationship has a correlation coefficient of 0.9965 and a standard error estimate of 2.337. The nominal spill rate over this data period is thus 0.0314 spills per million tons of pertroleum throughput. The maximum and minimum rates are 0.0349 (+11%) in 1975 and 0.0232 (-26%) in 1977.

3.3.1.2 Regional Level - Reference to the areal number density plot of Figure 3-4 indicates that there are few geographic regions that have historically experienced a large enough number of major

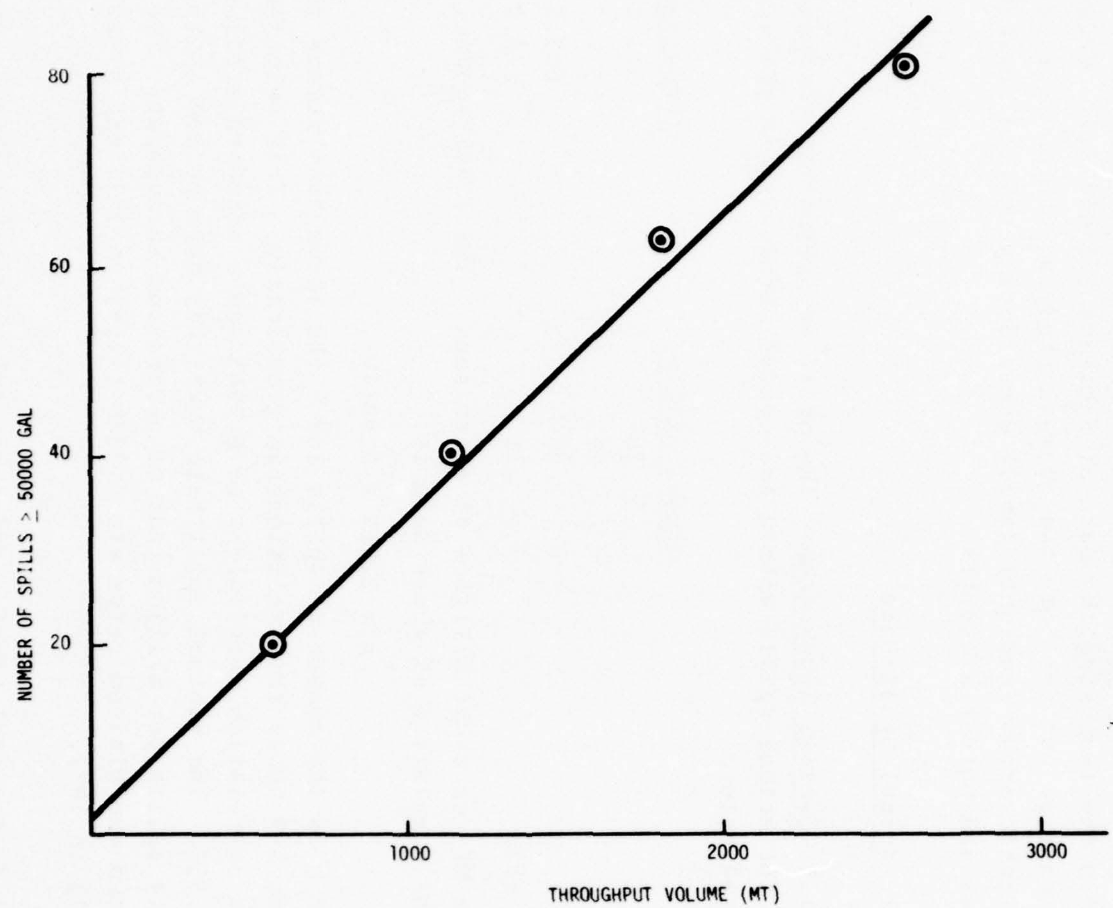

FIGURE 3-9. NUMBER OF OIL SPILLS ≥ 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT VOLUME (MT) 1974-1977

spills to be examined as separate entities. In fact, only four such regions can be tentatively identified: Greater New York with 12 spills, Delaware Bay with 7, the Louisiana Coast with 19, and the Northern Coast of Texas with 8. No other region had more than 3 major spills in the four years of record.

From the considerations of Section 3.2, the regions noted above represent, nominally, 21.5, 4.7, 10.5 and 15.2 percent, respectively, of the total annual waterborne petroleum throughput volume. Least square fits to the regional spill and throughput data are as follows:

Greater New York: $n = -0.171 + 0.0212V$

Delaware Bay: $n = 0.0627V$

Louisiana Coast: $n = 0.852 + 0.0682V$

North Texas Coast: $n = 0.818 + 0.0193V$

where once again n is the number of spills and V is the throughput volume in millions of short tons. The associated correlation coefficients and standard errors of estimate are as follows:

	Correlation Coef.	Standard Error
Greater New York	0.991	0.567
Delaware Bay	0.978	0.575
Louisiana Coast	0.995	0.631
North Texas Coast	0.976	0.596

As with the overall study region, these regional relationships indicate a very high degree of correlation between spill rate and throughput volume. These relationships are shown graphically in Figure 3-10, along with that of the nationwide average for comparison. From these plots it is evident that there can be considerable variation in spill rate from region to region. However, for regions other than those identified here, there is little choice but to apply the nationwide average.

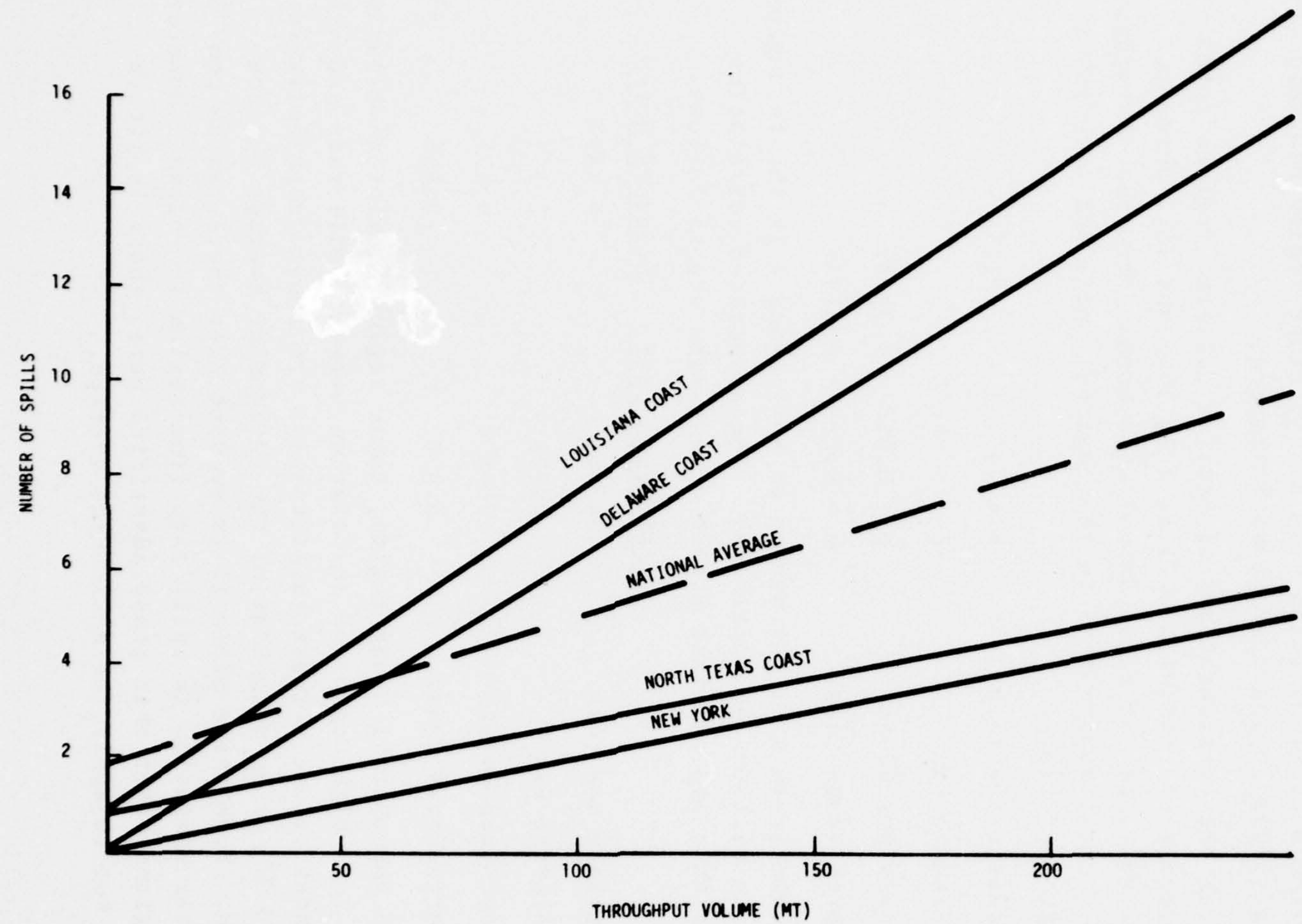

FIGURE 3-10. LEAST SQUARES FITS TO NUMBER OF SPILLS $\geq$ 50,000 GALLONS VS. THROUGHPUT VOLUME (MT) FOR SELECTED GEOGRAPHIC REGIONS

3.3.2 Potential Spill Data

3.3.2.1 MOSIS File Data - The attempt to correlate potential spills in the MOSIS file with petroleum throughput did not meet with the same success reported above. This should be apparent from the annual potential spill data summarized below for the overall study area and the selected geographic regions.

Year	Overall	New York	Delaware Bay	Louisiana Coast	North Texas
1974	25	10	4	0	0
1975	28	6	7	0	0
1976	14	0	1	0	0
1977	9	0	1	1	0

Although some degree of correlation can be inferred for the overall study region, there is no meaningful degree of correlation in the sub-regions. The reasons for this are related to many questions as to the definition of potential spills and/or the manner in which they have been reported in the past. Due to this lack of correlation, these potential spill data were not further considered in this study.

3.3.2.2 USCG Casualty File Data - The lack of success met in the attempt to use the potential spill data available to the MOSIS file led to consideration of the use of those incidents reported in the USCG Casualty file which could be potential sources of oil spills. The data available for such consideration spanned the time period from FY1972 to FY1975. During this period over 20,000 tanker and barge casualties were reported. Vessels of greater than 10000 GT were involved in some 2180 or 11% of these incidents which were distributed by cause as summarized in Table 3-2. Identification of incidents where there is a potential of a spill $\geq$50,000 gallons is not possible, directly from the casualty file. The format used in the computerized casualty data management file was developed to facilitate the use of these casualty data by permitting the rapid sort on and/or retreival of selected data such as that shown in Table 3-2. The number of data elements required to characterize

TABLE 3-2. TANK VESSEL CASUALTIES IN U.S. WATERS
FY 1972-1977

Tankships, Tank Barges, Foreign Flag Tankers > 10,000GT

Nature	Inland*	International*	Total
Collisions	337	58	395
Groundings	679	43	722
Rammings	501	24	525
Explosions/Fires	69	14	83
Capsizing/ Foundering	22	10	32
Weather	6	42	48
Cargo Only	1	0	1
Material Failure	193	130	323
Other	47	4	51
Totals	1885	325	2180

*Pertains to Inland and International Rules of the Road.

an incident for casualty evaluation purposes precludes the inclusion of sufficient ancillary data for spill potential assessment. The requisite data for this purpose can be had only through review of the narrative reports on file for each incident. Because of the number of incidents to be evaluated and the uncertainty of a useful end-product, a detailed evaluation of the casualty file for spill potential was not undertaken during this study, and no potential spill data were used in subsequent analyses.

3.4 SPILL THREAT ANALYSIS

The methodology employed here to estimate probabilities of oil spill occurrence was taken from Devanney and Stewart (Reference 3-2). The application of this methodology requires the acceptance of three basic assumptions: the fundamental assumption that meaningful estimates of future spill incidents can be based on past experience, plus the two further specific assumptions (1) that spills occur independently of each other (i.e., as a Poisson process) and (2) that the number of spills is proportional to the volume of petroleum throughput. The data of the preceding sections are quite supportive of these assumptions.

The referenced methodology is developed from the assumption that spill experience is a Poisson process. If, within this process, the intensity, λ, is known, the probability density of the number of spills can be determined from the expression:

$$p(n|\lambda,t) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$$

where t is the amount of exposure contemplated and λ is the mean spill rate in spills per unit exposure.

Nominal spill rate as a function of throughput volume was examined in Section 3.3 where a high degree of correlation was noted. However, this correlation does not imply certainty. Thus, for example, past experience of ν spills in τ volume throughput does not necessarily imply that $\lambda = \nu/\tau$. In the limit, of course, the larger ν and τ the more likely it is that λ approaches ν/τ. However, with a limited data base, which is most certainly the

case here, λ is most appropriately considered an uncertain quantity represented by a probability density about a known historic experience.

In the referenced development (Reference 3-2), it was assumed that, after having observed ν spills in τ volume throughput, the density on λ could be defined as a Gamma distribution of the form

$$f(\lambda|\nu,\tau) = \frac{e^{-\lambda\tau}(\lambda\tau)^{\nu-1}\tau}{(\nu-1)!} .$$

This density is the vehicle through which the fundamental dependence on past spill experience enters the analysis as a prognosticator of future events.

Having defined this relationship, it is a simple matter to obtain the density of the number of future spills to be expected to occur on the basis of a particular throughput volume. Thus:

$$p(n|t,\nu,\tau) = \int_0^\infty p(n|\lambda,t)f(\lambda|\nu,\tau)d\lambda .$$

This density function can be reduced algebraically to the form:

$$p(n|t,\nu,\tau) = \frac{(n+\nu-1)!\ t^n\tau^\nu}{n!(\nu-1)!\ (t+\tau)^{n+\nu}}$$

This function defines the probability density distribution of experiencing n spills for a given throughput, t, wherein past experience has noted a total of ν spills over an exposure of τ units. One of the more notable advantages of making predictions of oil spill frequency in the form of a probability distribution is that such data give not only an estimate for the most likely number of spills that would be expected to occur, but some measure of the uncertainty of that prediction. These considerations are applied to the problem at hand in subsequent sections as it pertains to the overall study region and to those specific geographic regions that could be identified from the MOSIS file as warranting individual attention.

3.4.1 Overall Study Area

The probability density distribution described above was applied to the spill and throughput data of Section 3.3.1 to determine overall spill threat spectra for the study region. This was done in parametric fashion about throughput volume to permit generalized application to most geographic regions of concern. The discrete threat spectra so determined are shown in Figure 3-11 (parts a, b, c, and d), along with an indication of the mean (or expected value) of the distribution as shown in alternative forms in Figures 3-12 and 3-13. The first, Figure 3-12 is a cumulative plot of the information contained in the threat spectra of Figure 3-11, indicating the cumulative probability of n or fewer spills of 50,000 gallons or more as a function of throughput volume. The cumulative is convenient in that the probability that the actual number of spills will fall between any two specified values can be determined by simply subtracting the cumulative associated with the higher value from that associated with the lower. Although smooth curves are shown in Figure 3-12 connecting the high points of the cumulative steps, it must be remembered that, in the real world, spills occur in integral units and these integral points are the only ones that have any physical meaning.

Figure 3-13 is a restatement of the threat wherein the probability that there will be at least n spills of the magnitude considered for the indicated throughput volumes is presented. This format is particularly useful in estimating bounds on spill expectations.

The use of the information in these figures to provide "average" estimates throughout the study area requires only an estimate of the throughput volume experienced by a given area over an arbitrary time period since, by this treatment, prior spill experience becomes an endogenous parameter with throughput volume being the exogenous determining function. The range on parametric throughput has been made sufficiently wide to accommodate almost any regional throughput on an annual basis, at least over the next decade. It can also accommodate many regions over extended periods of time.

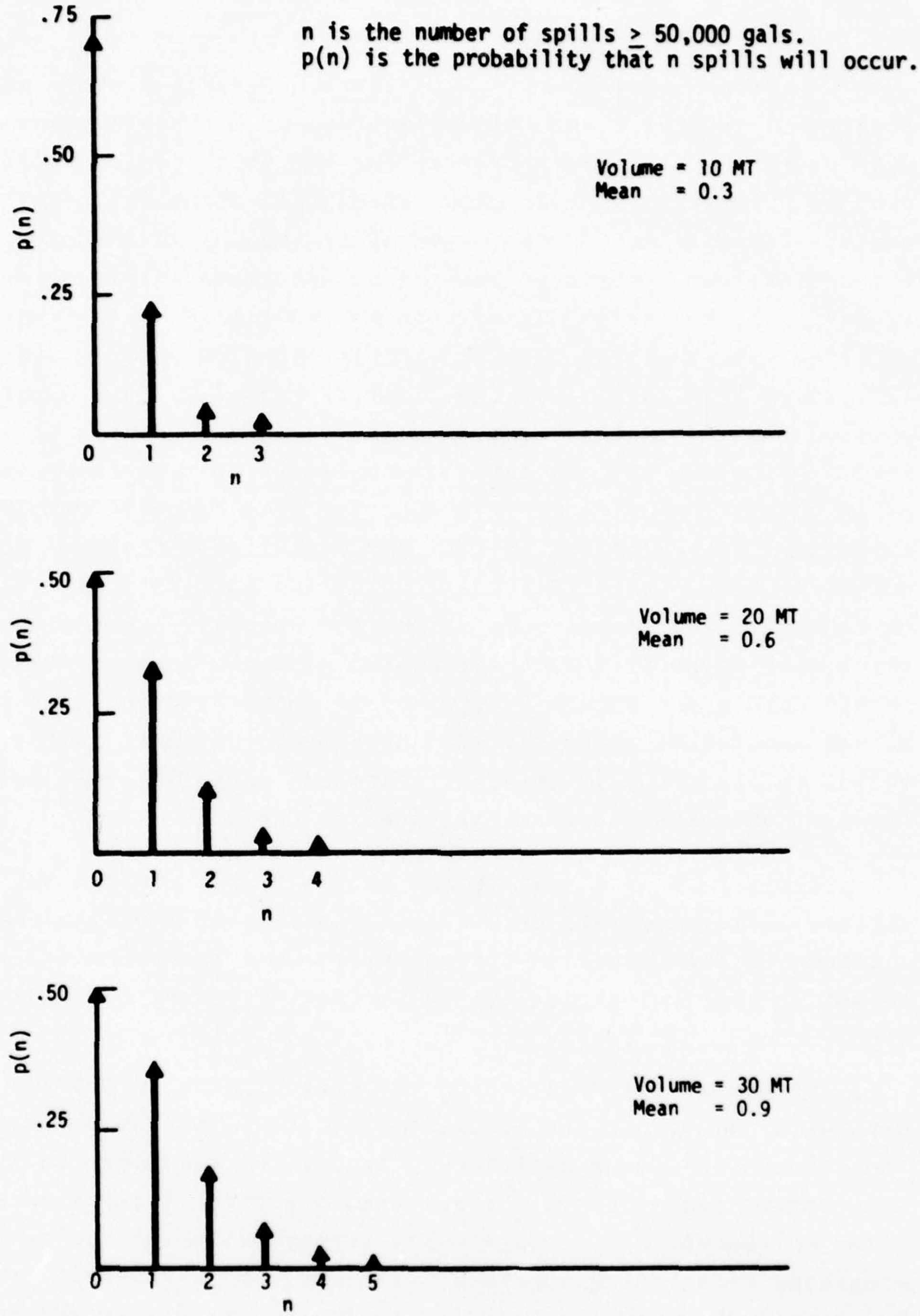

FIGURE 3-11(a). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS

n is the number of spills $\geq$ 50,000 gals.
p(n) is the probability that n spills will occur.

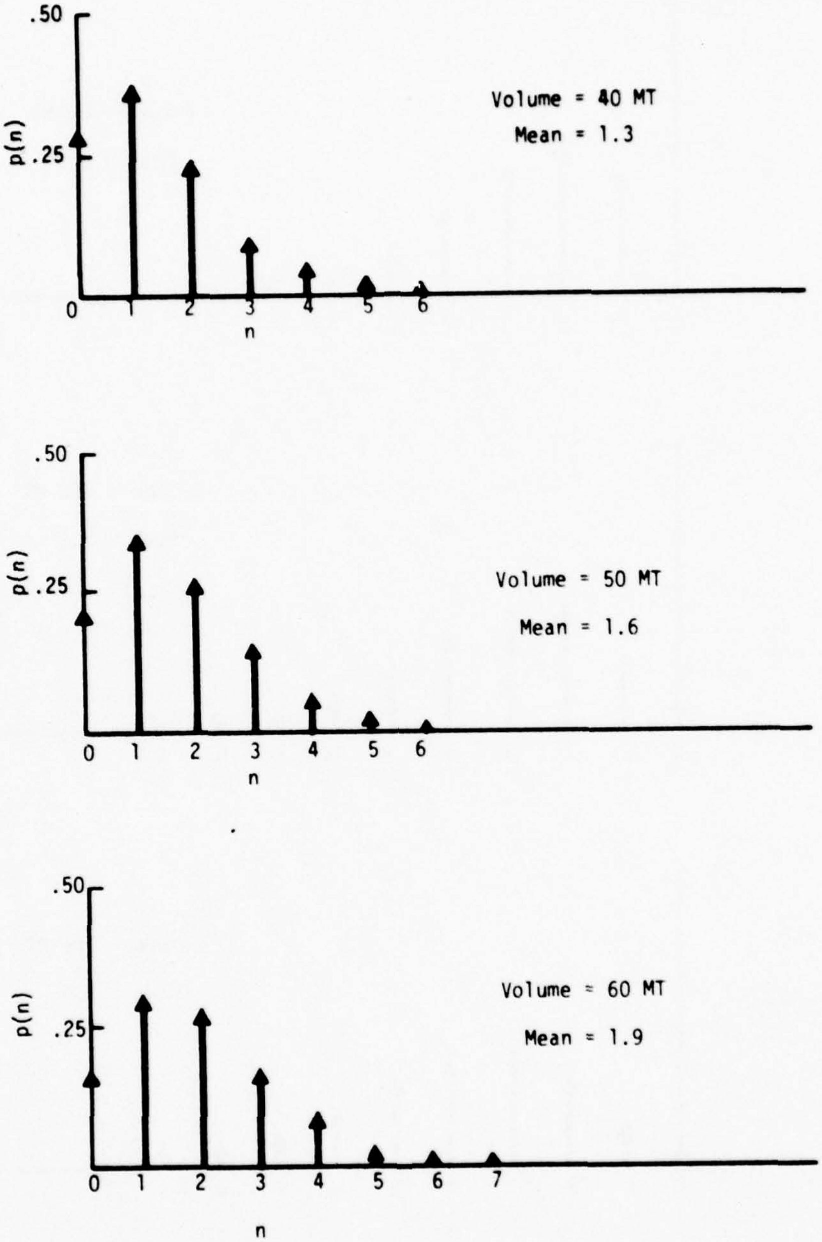

FIGURE 3-11(b). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS

n is the number of spills $\geq$ 50,000 gals.
p(n) is the probability that n spills will occur.

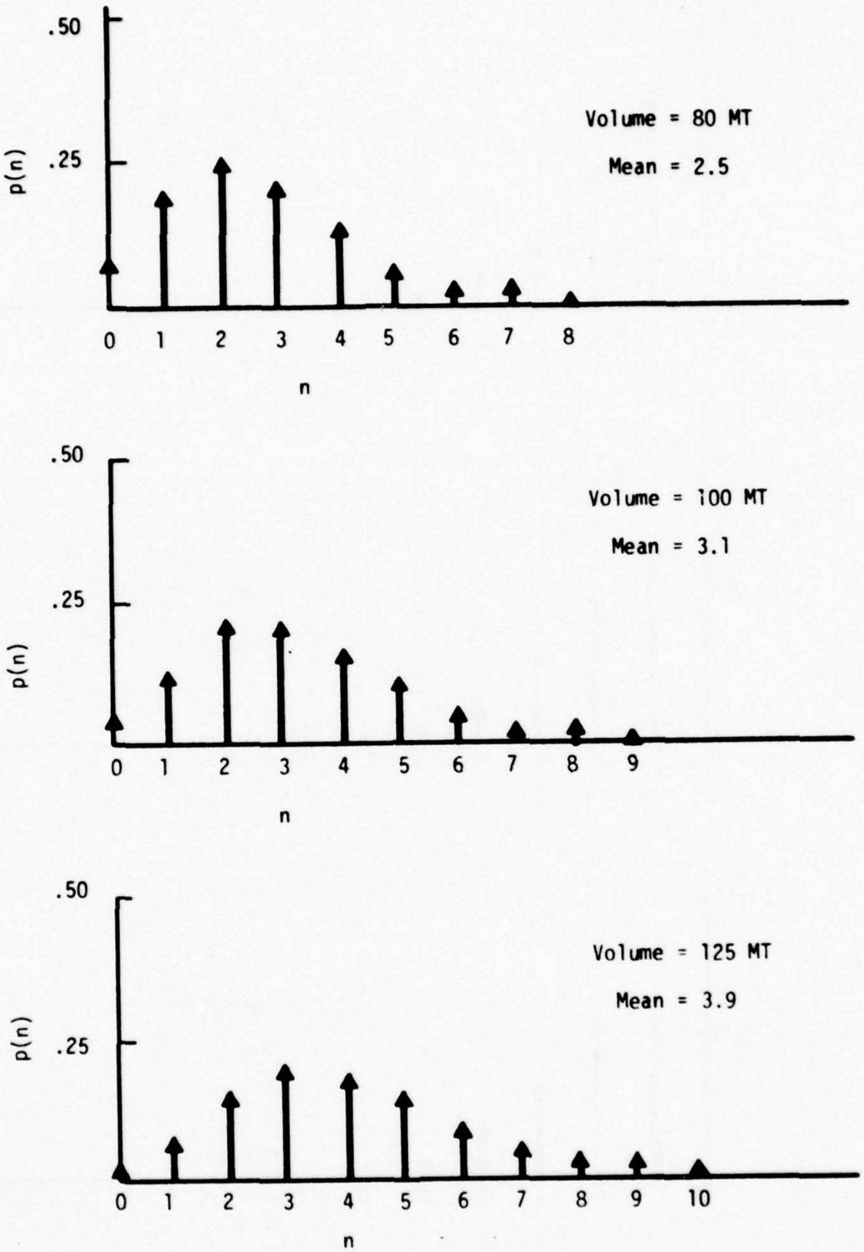

FIGURE 3-11(c). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS

n is the number of spills $\geq$ 50,000 gals
p(n) is the probability that n spills will occur.

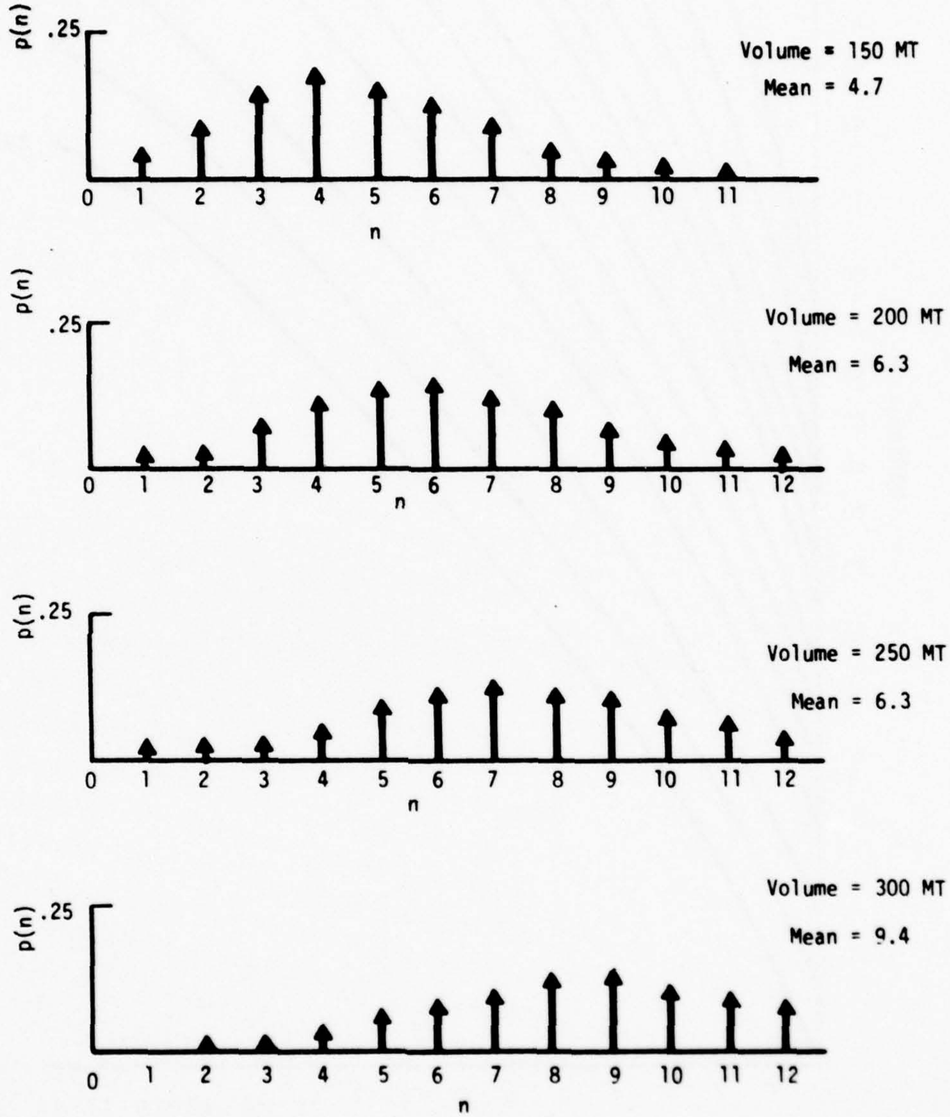

FIGURE 3-11(d). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS

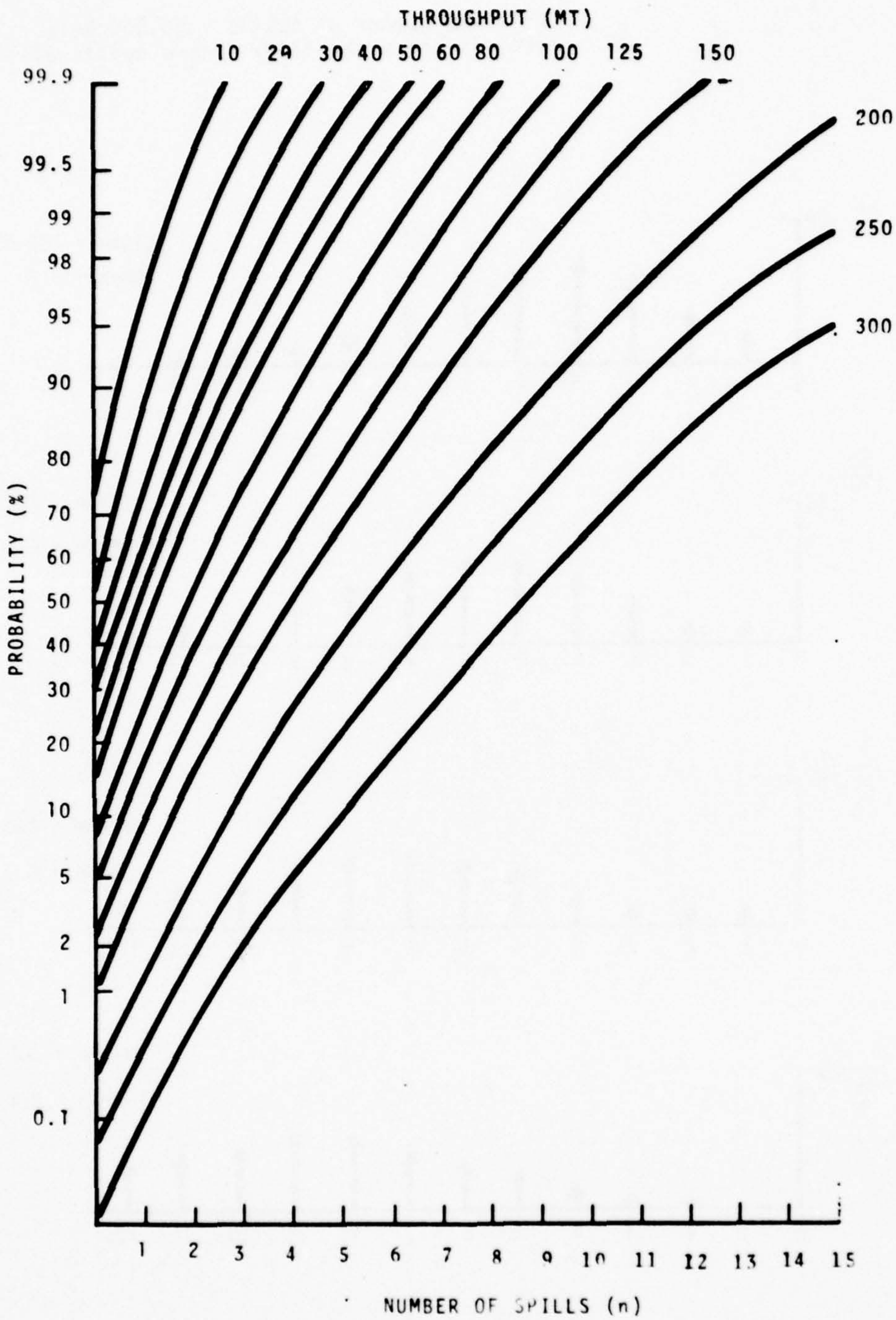

FIGURE 3-12. PROBABILITY OF n OR LESS (≤n) SPILLS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS

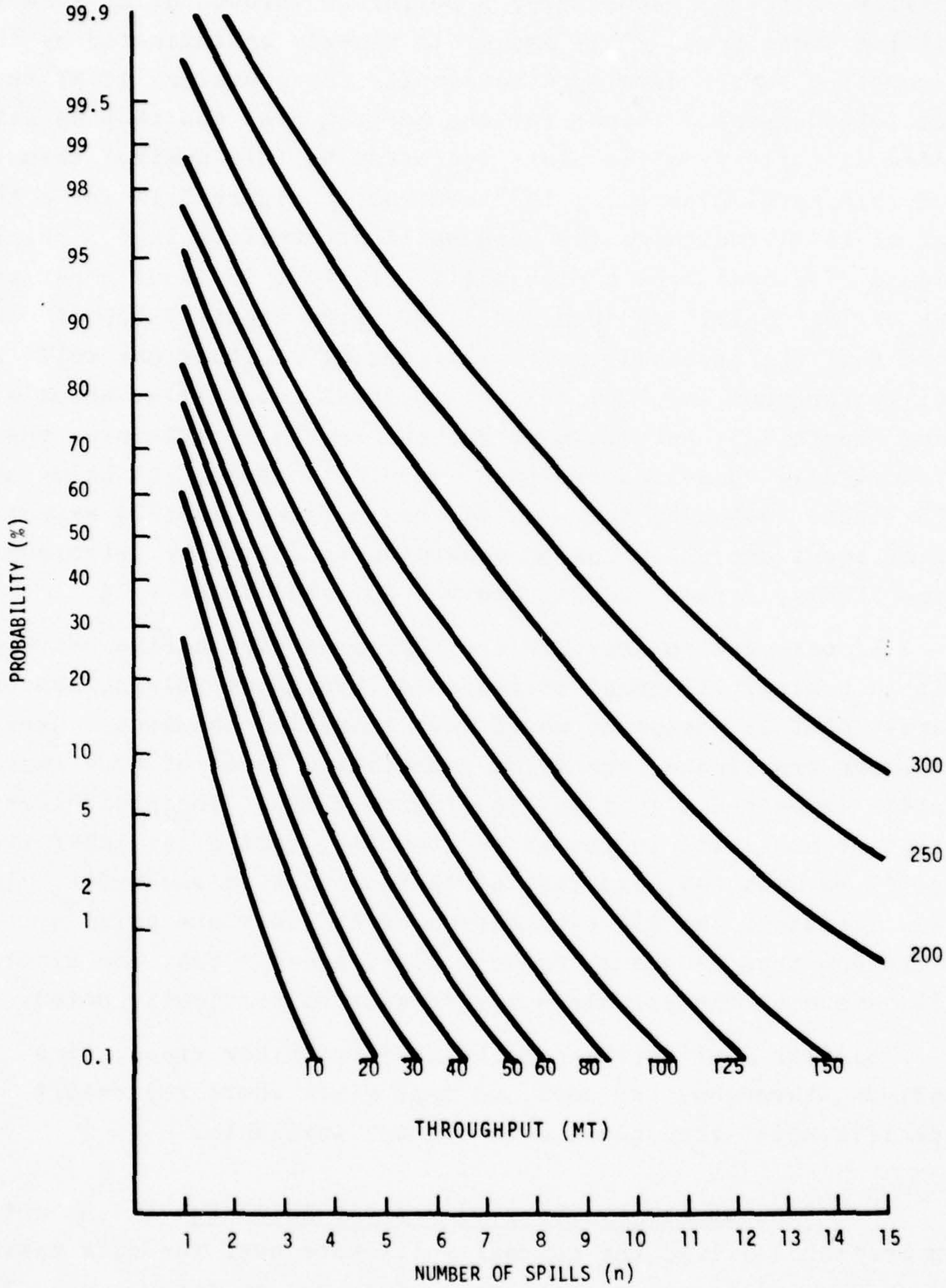

FIGURE 3-13. PROBABILITY OF AT LEAST n (≥n) SPILLS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS

Thus, for example, during calendar year 1975, the area about Norfolk, Virginia experienced a petroleum throughput of some 11.5 million short tons. This amount is closely approximated by the parametric curves developed nationally for a nominal 10 MT throughput. The expected threat for the Norfolk area can thus be estimated directly from the plots representing this nominal throughput. For this particular case, the spectrum of Figure 3-11 for a throughput of 10 MT indicates the mean spill probability is 0.3 spills. Figure 3-12 indicates a probability of about 99.5% of experiencing two or less spills in such a region. From Figure 3-13, it can be seen that the probability of experiencing at least one spill with this throughput is about 27%, of at least two spills, about 4%. From Figure 3-5, petroleum throughput in the Norfolk area has historically consisted of approximately 1% crude, 72% heavy and 27% light. Assuming this mix to remain fixed, the 27% expectation of at least one spill can be separated to threat by petroleum type thusly: crude - 0.3%, heavy - 20%, and light - 7%.

If one were to consider the same area over a five-year period with a nominal 2% annual increase in throughput volume, approximately 60MT of petroleum would have transited the area. Over this exposure experience, the 99.5% probability level of n or fewer spills is extended to 6 spills (Figure 3-12). The probability of at least one spill increases to some 85%, that of at least two spills becomes 60%, and that of three spills is about 30%. In this instance, the 85% expectation of at least one spill by petroleum type becomes: crude - 0.9%, heavy - 62%, and light - 22%, assuming the petroleum mix remains as previously noted.

Similar applications can be made for other areas, time periods, throughput volumes and type mixes where regionally specific spill-throughput data are not available.

Sensitivity to Observed Extreme Spill Rates - As noted in Section 3.3.1.1, the nominal spill rate over the data period was 0.0314 spills per million tons of petroleum throughput. The upper and lower extremes of the observed spill rates were 0.0349 (+11%) and 0.0232 (-26%), respectively. These departures from the

nominal were examined to determine the sensitivity of the information contained in Figures 3-12 and 3-13 to such excursions. The results of this analysis are summarized in Figure 3-14 where the upper, lower, and nominal expectancies of n or less spills are plotted as a function of throughput for the 50% and 95% probability levels. These plots indicate that spill expectancies resulting from the extreme observed spill rates are about plus or minus one spill from the nominal over the expected range of individual port throughput experience. Hence, the spill probabilities reported in the preceeding section are not overly sensitive to departures from the nominal spill rate and can be used with some degree of confidence in the future if spill rates fall within the noted extremes.

3.4.2 Regional Level

As noted in Section 3.3.2, there are four geographic regions wherein threat spectra other than the nationwide average can be tentatively identified: Greater New York, Delaware Bay, the Louisiana Coast and the Northern Texas Coast.

The cited regions were individually subjected to the treatment described above for the overall study region. The results for each region are summarized separately in Figures 3-15 through 3-18, where estimates of spill probabilities are shown parametrically for nominal current and future (1980, 1990) throughput volumes. These figures contain the combined information content of Figures 3-12 and 3-13, as previously described.

It is immediately obvious from these charts that, although there is a high degree of spill-throughput correlation in each region, a marked variablity of spill potential can be expected from one geographic region to another. The four regions cited account for 57.6% of the spills in the MOSIS file and 51.9% of the throughput. The spill-throughput relationship in each of the noted

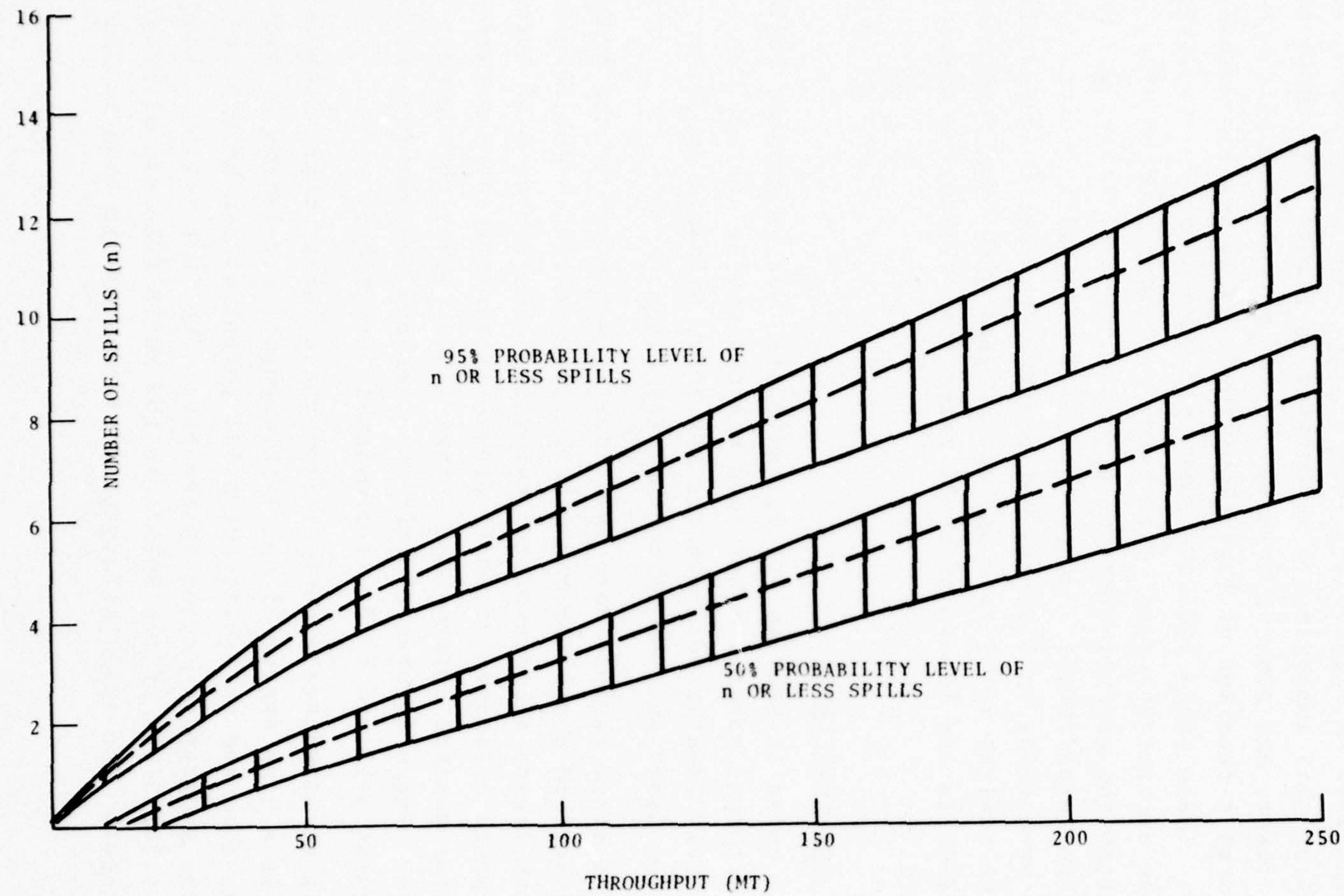

FIGURE 3-14. SENSITIVITY OF SPILL EXPECTANCIES TO EXTREME OBSERVED EXCURSIONS ABOUT THE NOMINAL SPILL RATE

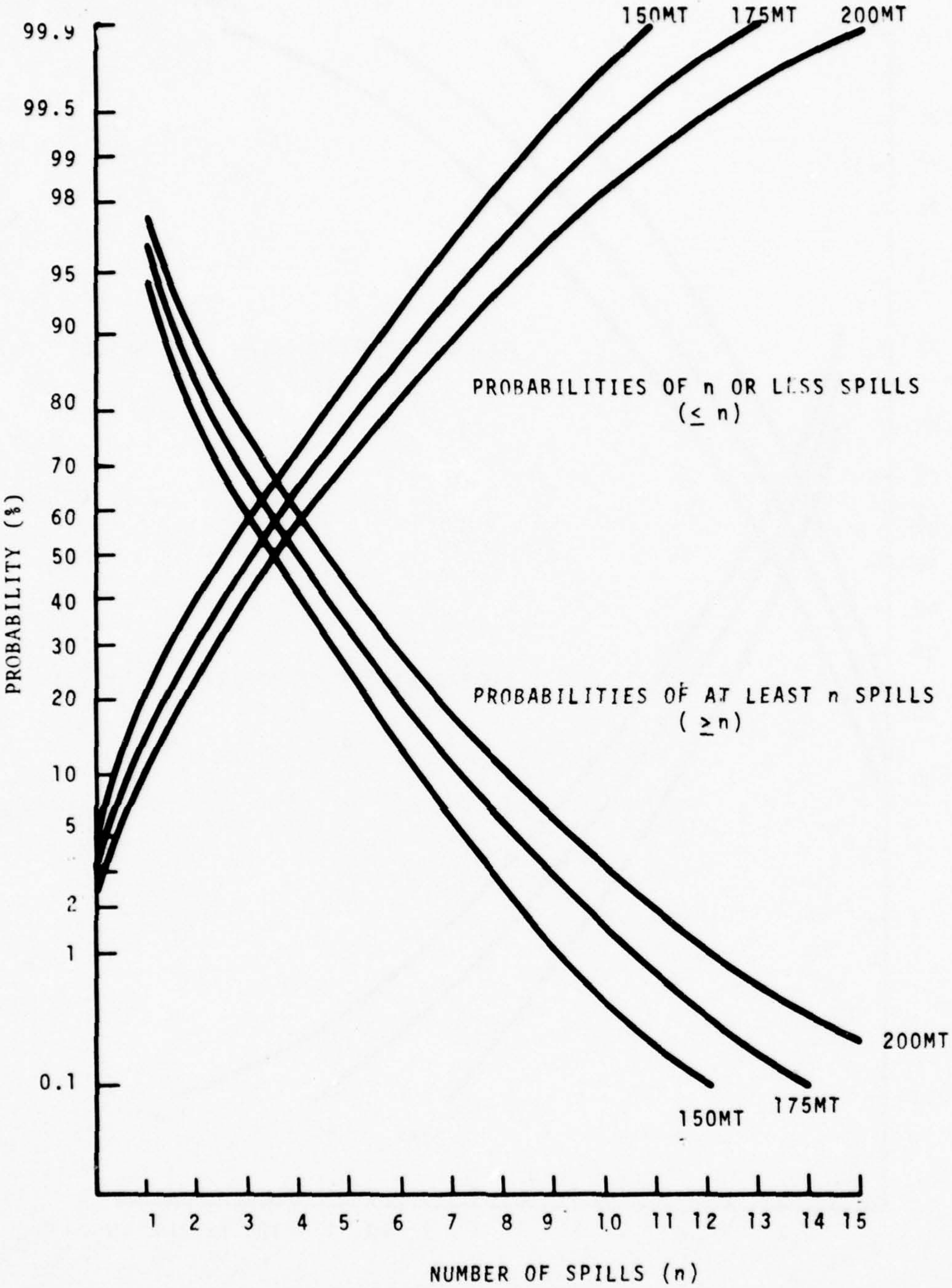

FIGURE 3-15. PROBABILITIES OF SPILLS > 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS --- GREATER NEW YORK REGION

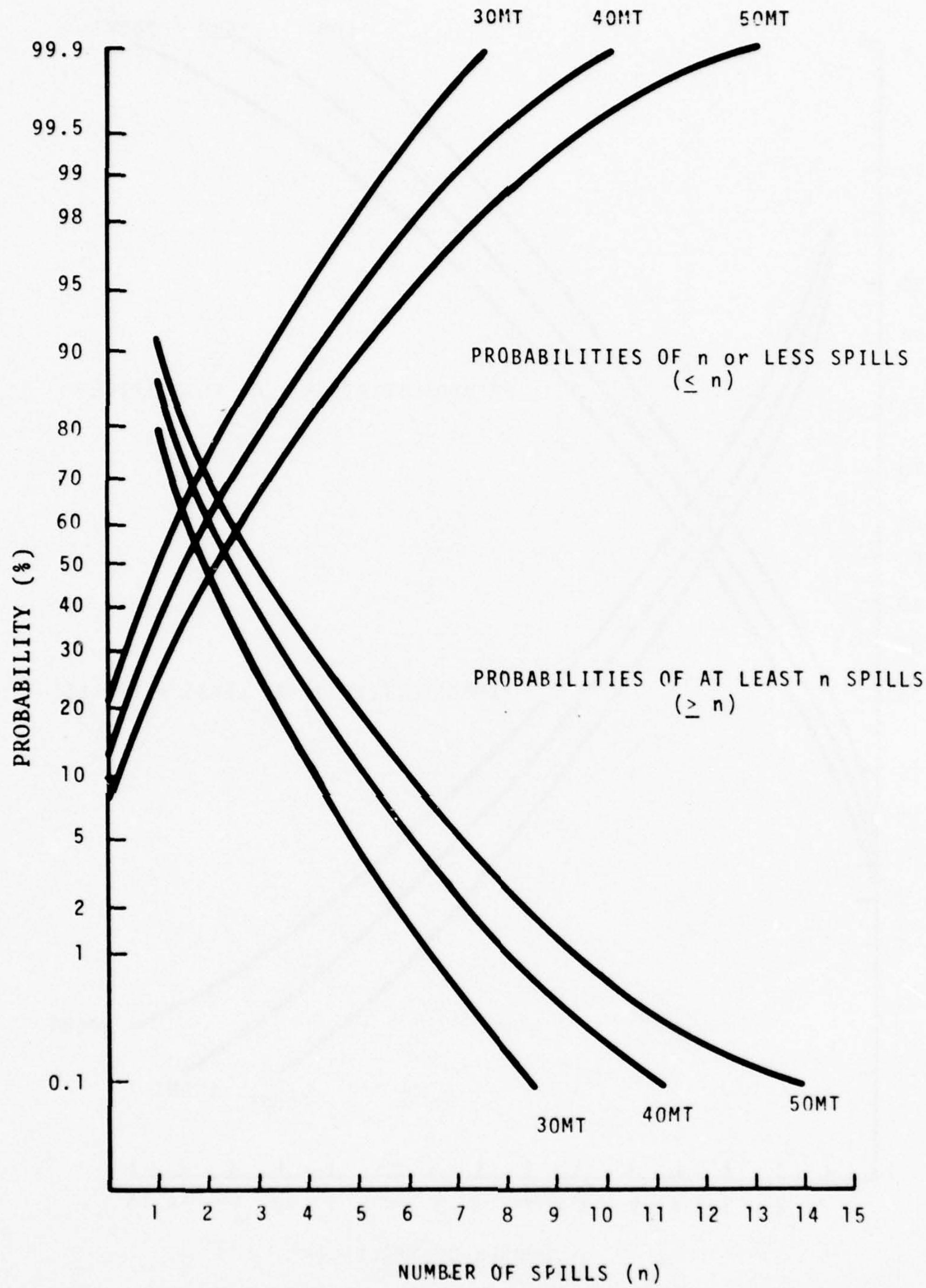

FIGURE 3-16. PROBABILITIES OF SPILLS > 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS -- DELAWARE BAY REGION

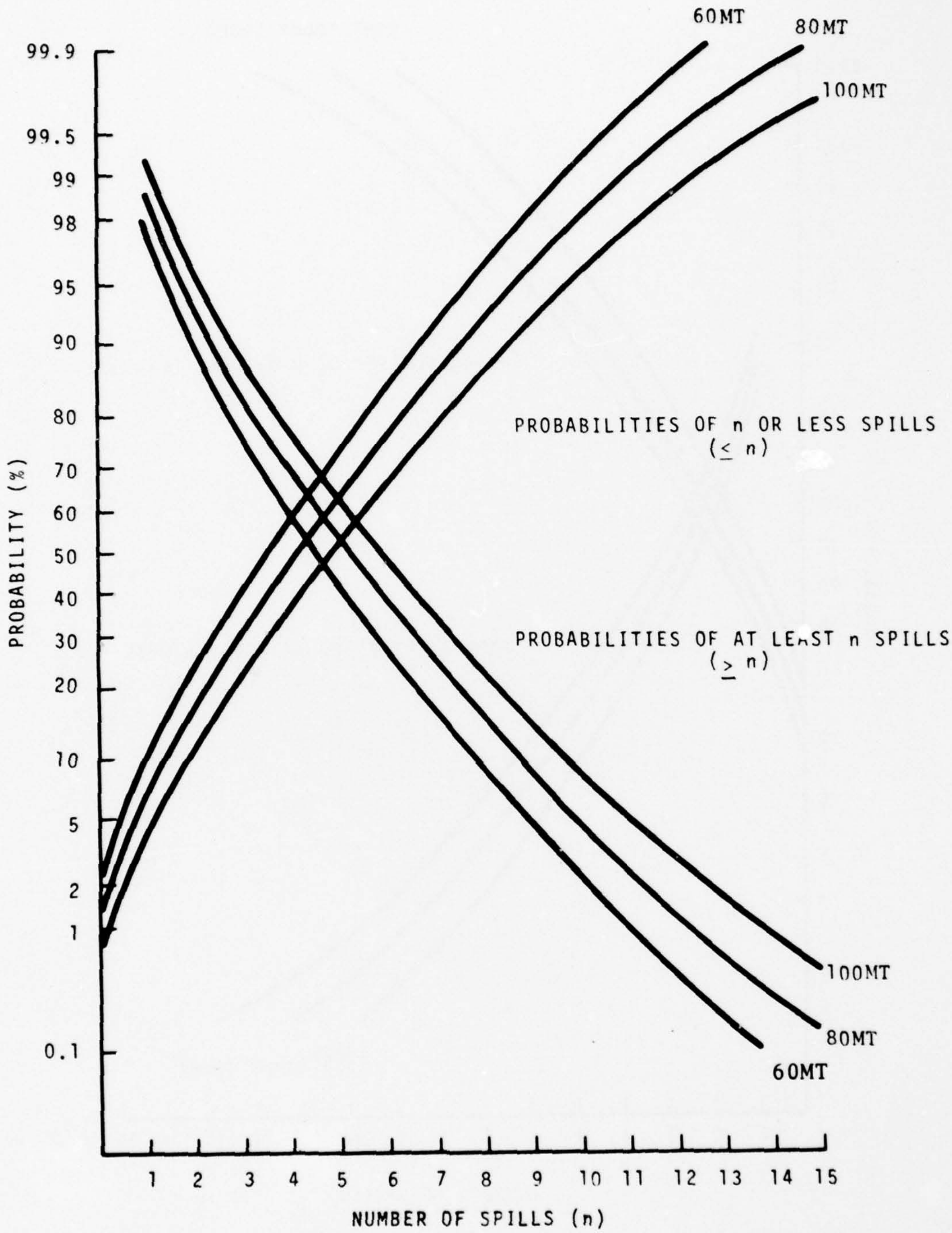

FIGURE 3-17. PROBABILITIES OF SPILLS > 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS -- LOUISIANA COASTAL REGION

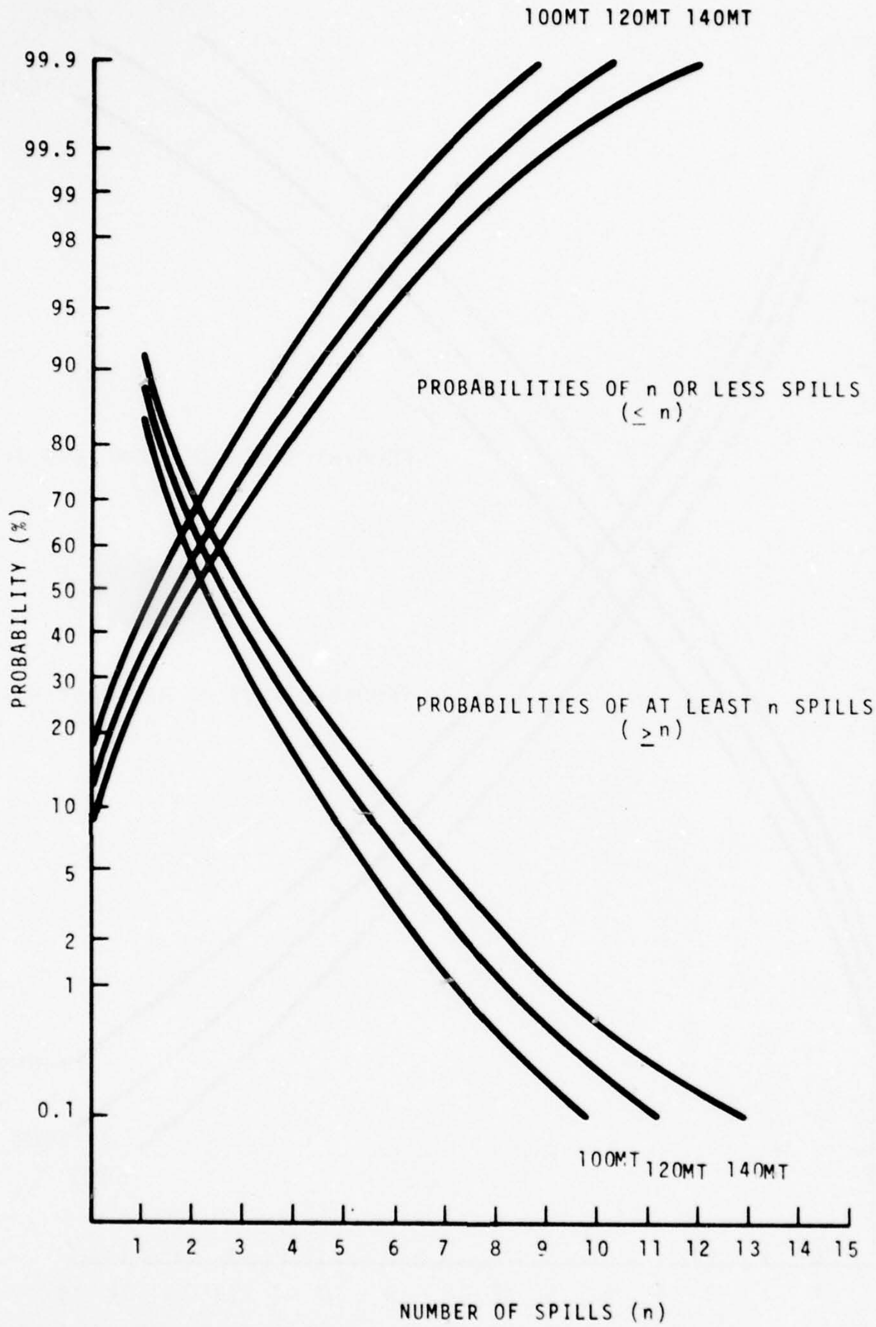

FIGURE 3-18. PROBABILITIES OF SPILLS > 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS -- NORTH TEXAS COASTAL REGION

regions taken individually is far from this seeming one-to-one basis. This is evident from the regional spill-throughput statistics as summarized below:

Region	No. of Spills	% of Spills	% of Throughput
Gr. New York	12	15.0	21.5
Delaware Bay	7	8.8	4.7
Louisiana Coast	19	23.8	10.5
No. Texas Coast	8	10.0	15.2

Surprisingly enough, the region that one would intuitively suspect as being the most culpable, Greater New York, has a spill rate much below the nationwide average. This region does, however, rank quite high (number 2) on the basis of the number of spills. This is not at all surprising considering its share of the nationwide throughput. The real culprit, both as to the spill rate and the number of spills, appears to be the Louisiana Coast.

Delaware Bay and the North Texas Coast may be questionable regional choices because of the limited number of spills experienced. These regions have been included, however, to provide some degree of diversity since no other region experienced more than three spills in the time period considered. Of these two "candidates", the Delaware Bay region appears to be the higher risk area, comparable in rate to the Louisiana Coast.

3.4.3 Transient Tankers and Barges

In addition to the spill threat related to petroleum flow in or out of a given region, each region is also subjected to a further threat as a consequence of petroleum movement via transient tankers and barges en route to or from destinations outside the regions. A review of the Environmental Impact Statement for the LOOP deepwater port (Reference 3-7) reveals that spills from transient vessels are quite rare. As derived from that analysis, the expected rate of spills $\geq$ 50,000 gallons from transient tankers and barges is about 0.000245 spills per million tons of petroleum

throughput;* more than two orders of magnitude below the nominal national rate derived in Section 3.3.1.1. In keeping with the treatment of the preceeding sections the threat from transient tankers and barges was treated in a probabalistic manner, the results of which are summarized below:

PROBABILITY - p(n)

	TRANSIENT FLOW (MT)				
n	10	25	50	100	200
0	.9975	.9939	.9878	.9757	.9520
1	.0024	.0061	.0121	.0240	.0467
2	-	-	-	.0002	.0012

An estimate of the transient flow through any coastal region may be taken from Figures 3-6 and 3-7. Thus, for example, the annual transient flow through the Gulf of Mexico off the coasts of Mississippi, Alabama and the Florida Panhandle is about 70 MT. There is a better than 98% probability that no spill of the size considered will result from this level of activity; the probability of no more than one such spill is better than 99.98%. Since this region has the largest transient flow, it also has the greatest spill probability. Consequently, the Gulf Coast can be viewed as a worst case situation in that all other coastal regions will have lower spill probabilities. Some regions and their approximate annual transient flows are noted below:

Region	Transient Flow (MT)
Gulf Coast (as above)	70
Florida Coast (and straits)	45
Louisiana Coast	40
Mid Atlantic Coast	35
Baltimore Canyon	30
West England	10
West Coast	10

*Or one spill $\geq$ 50,000 for 4000 MT which is 5 times the total annual waterborne petroleum movement in the study area in 1977.

The West Coast transient flow may increase appreciably with increased movement of Alaskan crude it is quite unlikely, however, that future West Coast flow would exceed that of the Gulf Coast noted above.

3.4.4 Outer Continental Shelf Wellfields

Although numerous oil wells have been drilled in waters off the U.S. coast, large quantities of oil resources remain to be recovered from the Outer Continental Shelf (OCS). Most of the OCS oil recovery activity to date has been concentrated in the Gulf of Mexico with lesser activity off the California coast. Major potential areas off the Atlantic coast have yet to be explored.

In anticipation of the prospect of increased activity in the Gulf of Mexico and the imminent exploratory operations in the Atlantic, the USGS has conducted oil spill risk analyses for the proposed lease areas in the Atlantic and the Gulf of Mexico (References 3-8 and 3-11), These analyses, which address the spill potential over the production life of the lease area, are summarized below:

Area	Production Life (Years)	Total Yield (MT)	Number of Spills*
North Atlantic	20	25-100	2.8
Mid Atlantic	25	60-210	5.6
South Atlantic	25	40-150	3.8
Gulf of Mexico	25	225-300	7.8

The locations of the proposed lease areas are shown in Figures 3-19 - 3-22 (References 3-8 - 3-11). The existing lease areas in the Gulf of Mexico are shown in Figure 3-23 (Reference 3-12) and those off the California coast are shown in Figure 3-24 (Reference 3-13).

*Expected number of spills ≥ 50,000 gallons over the production life of the area.

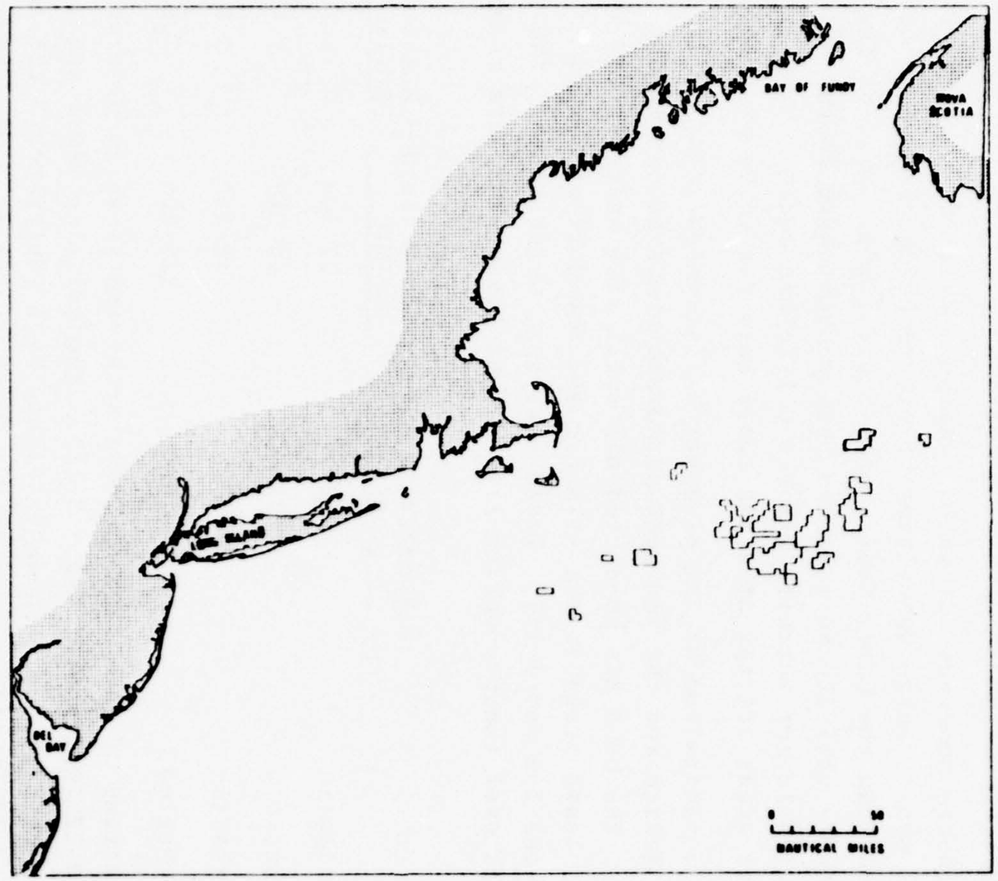

FIGURE 3-19. MAP OF THE NORTH ATLANTIC OUTER CONTINENTAL SHELF SHOWING SUBDIVISIONS OF THE LEASE AREA (REFERENCE 3-8)

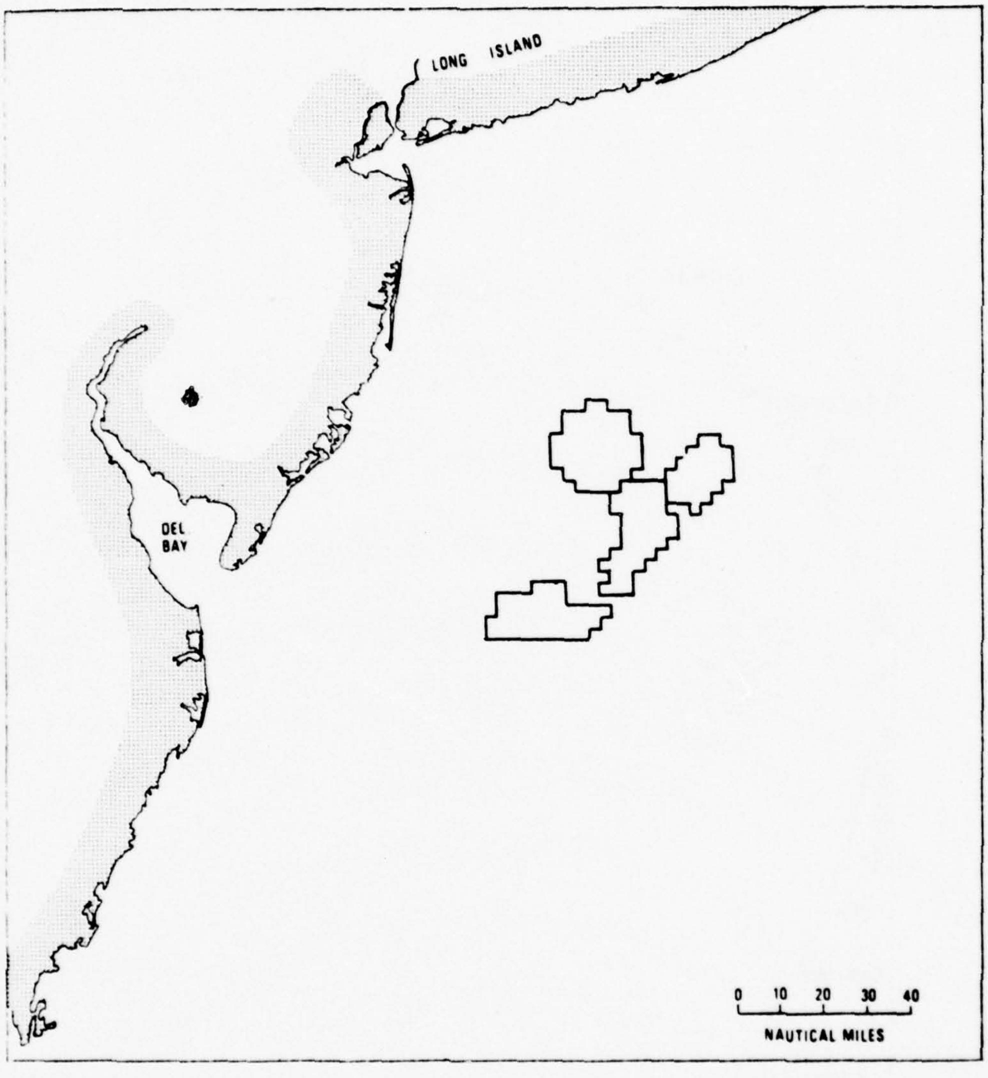

FIGURE 3-20. MAP OF THE MID-ATLANTIC OUTER CONTINENTAL SHELF SHOWING SUBDIVISION OF THE LEASE AREA (REFERENCE 3-9)

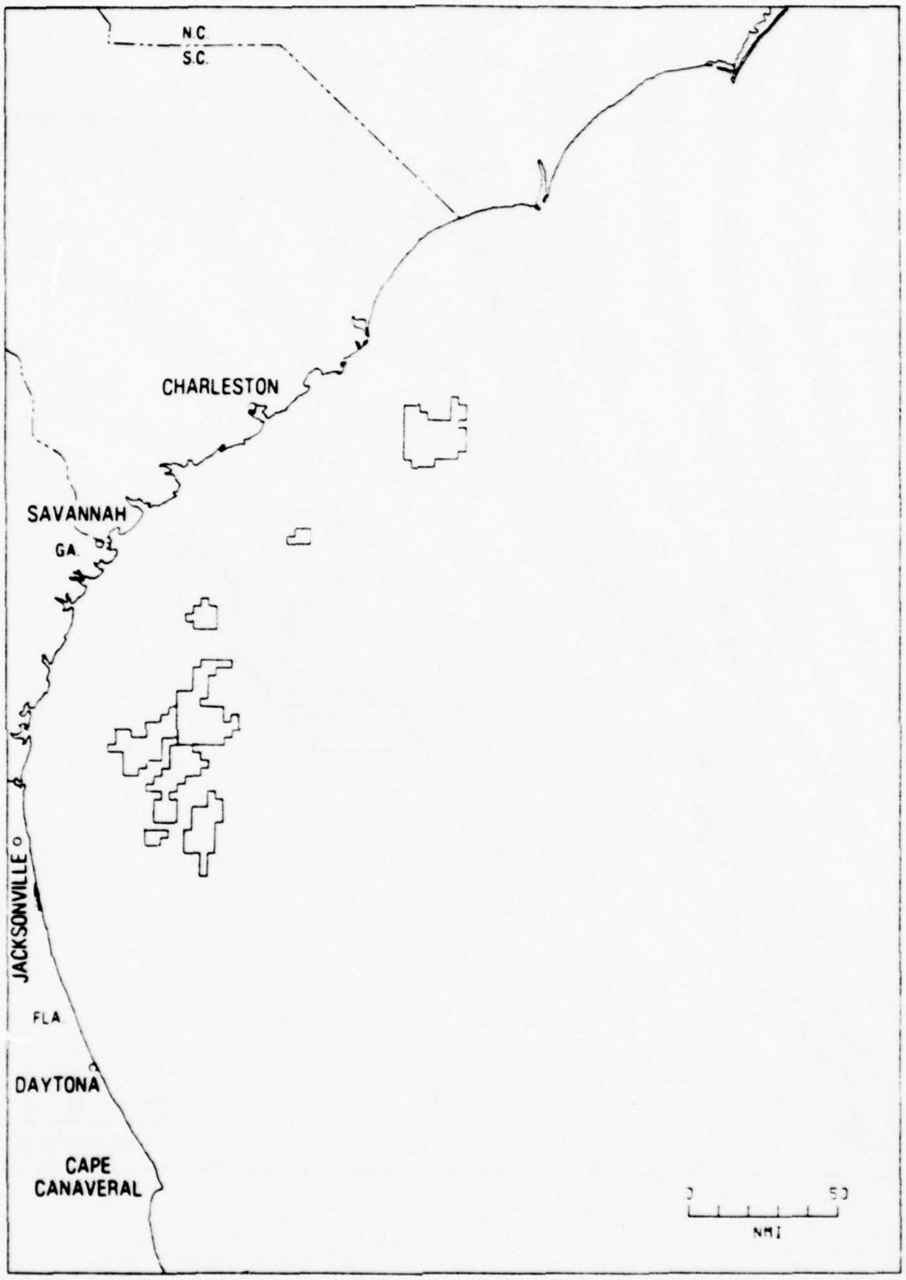

FIGURE 3-21. MAP OF THE SOUTH ATLANTIC OUTER CONTINENTAL SHELF SHOWING SUBDIVISION OF THE LEASE AREA (REFERENCE 3-10)

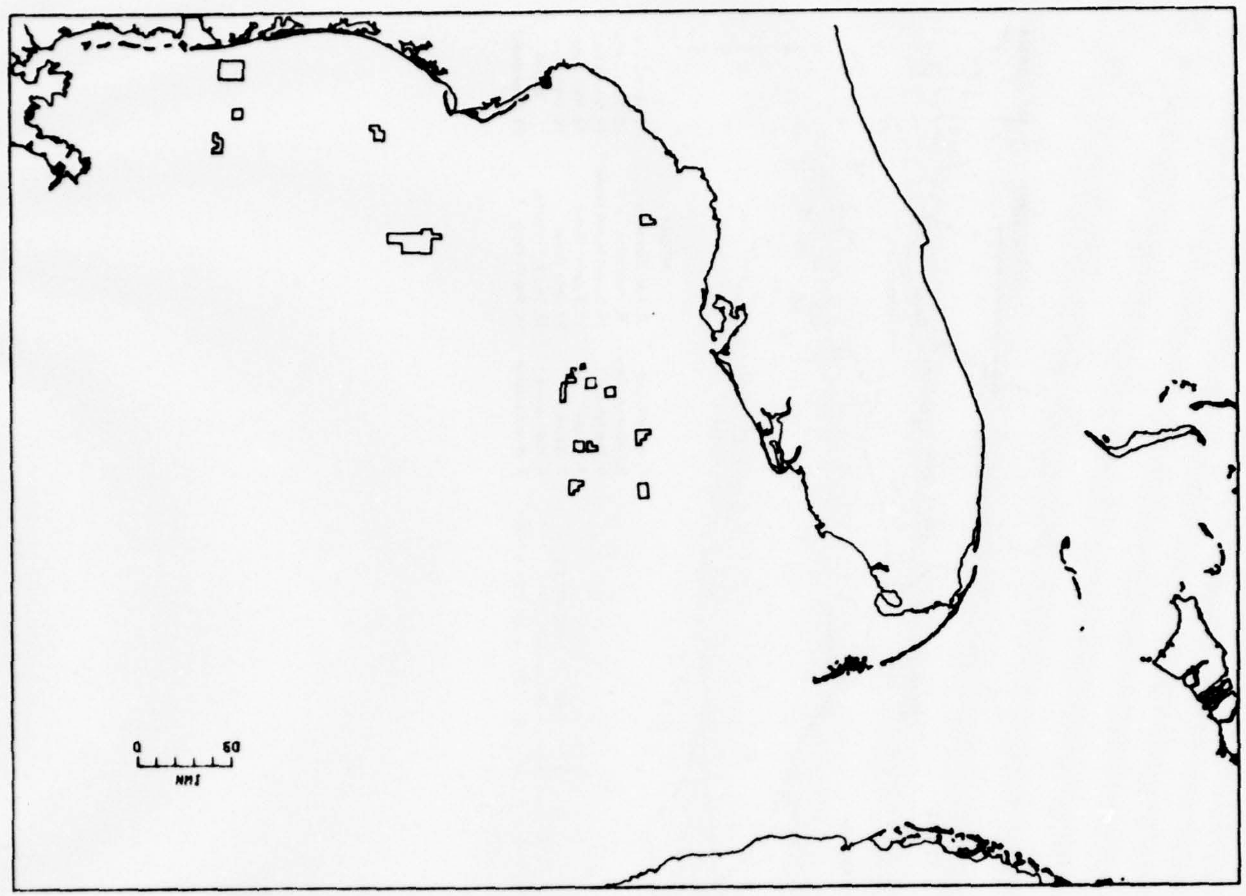

FIGURE 3-22. MAP OF THE EASTERN GULF OF MEXICO OUTER CONTINENTAL SHELF SHOWING SUBDIVISION OF THE LEASE AREA (REFERENCE 3-11)

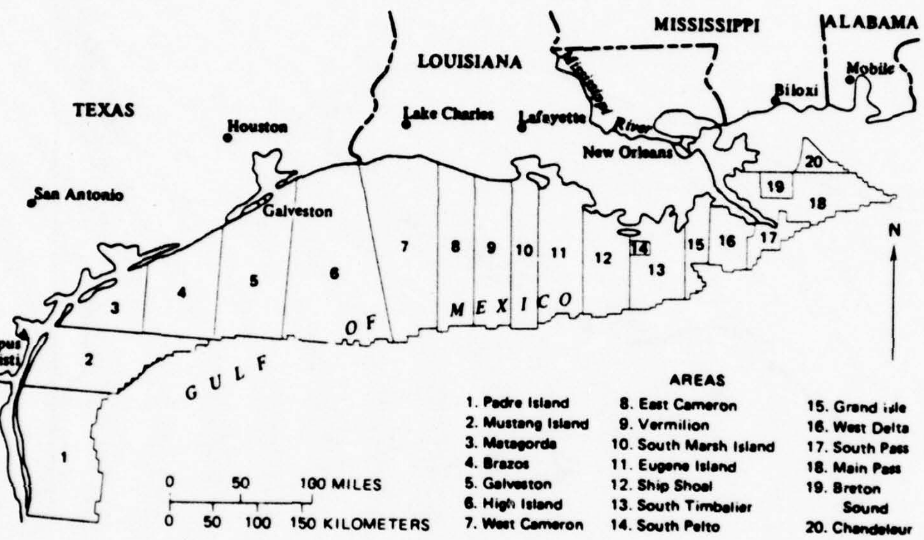

FIGURE 3-23. MAP OF THE WESTERN GULF OF MEXICO OUTER CONTINENTAL SHELF SHOWING EXISTING LEASE AREAS (REFERENCE 3-12)

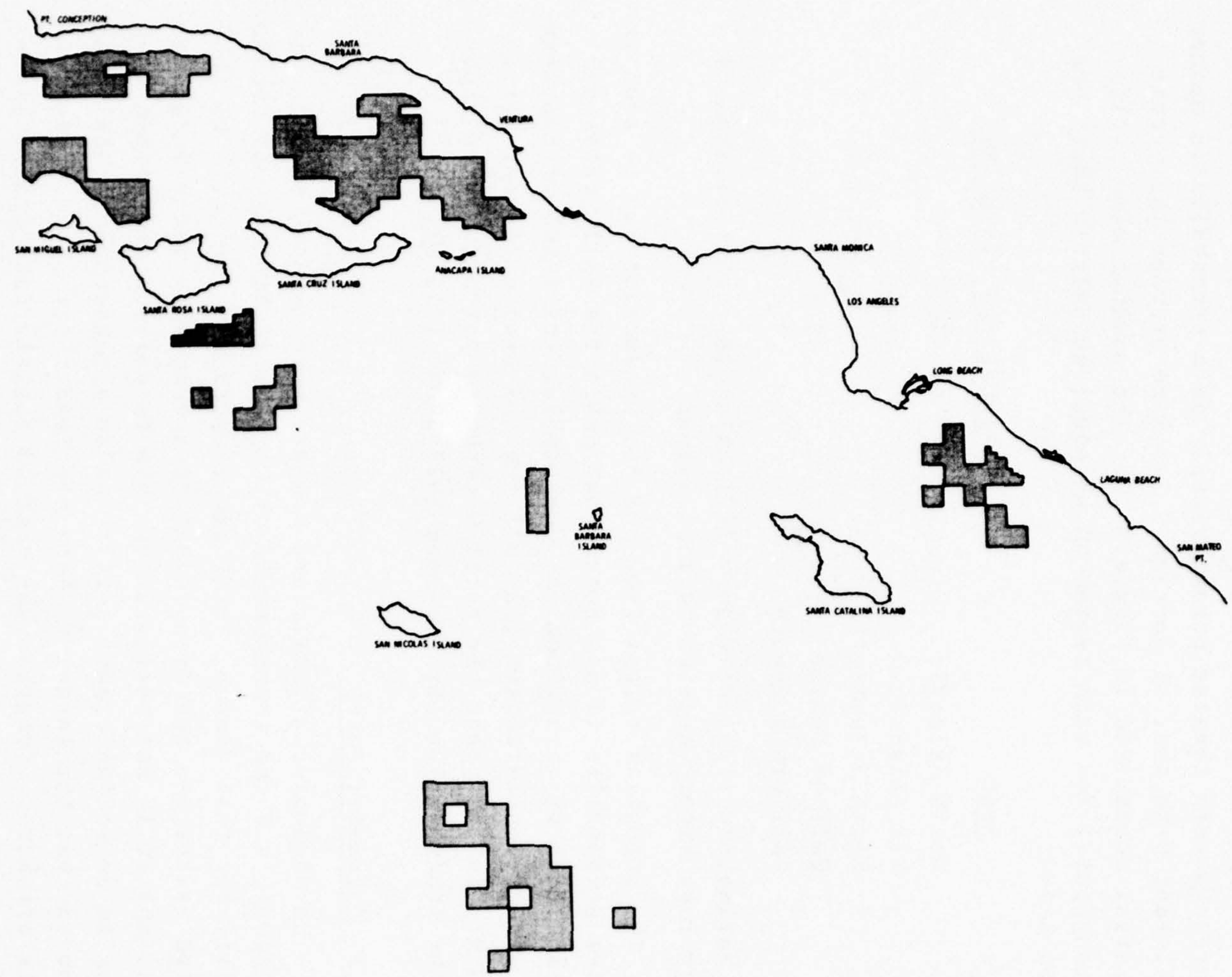

FIGURE 3-24. WEST COAST OUTER CONTINENTAL SHELF LEASE AREAS

The spill-yield (throughput) data taken from the cited references were treated parametrically in a probabalistic manner consistent with that of Section 3.3.1.1 to provide the threat potential summarized in Figure 3-25. The nominal mean yields (throughputs) for each region on an equal annualized basis are noted below:

Area	Annualized Yield (MT)
North Atlantic	3.1
Mid Atlantic	5.4
South Atlantic	4.8
Gulf of Mexico	10.5
California Coast*	3.4

The parametric plots of Figure 3-25 allow for consideration of excursions about these annualized values.

The potential threat from OCS oil production may be seen in better perspective if one notes that while the spill rates per million tons of throughput are comparable, the total of the mean OCS production estimates from all regions over a 25 year period (680 MT) is less than the total waterborne petroleum throughput in the study region for the year 1977 alone (775 MT).

3.4.5 Deepwater Ports

The economies of scale are nowhere more obvious than in oil transport, and the transport of oil by larger tankers has become a reality for this reason. With few exceptions, the ports of the United States are not deep enough to accommodate these large vessels, and it is not believed feasible to enlarge and deepen them in order to do so (Reference 3-14). As an alternative it has been proposed that the larger tankers off-load their cargo at deepwater ports offshore. Congress has enacted legislation, the Deepwater

*It is assumed that the spill risk encountered off the California coast is essentially the same as that determined by the USGS for the other areas.

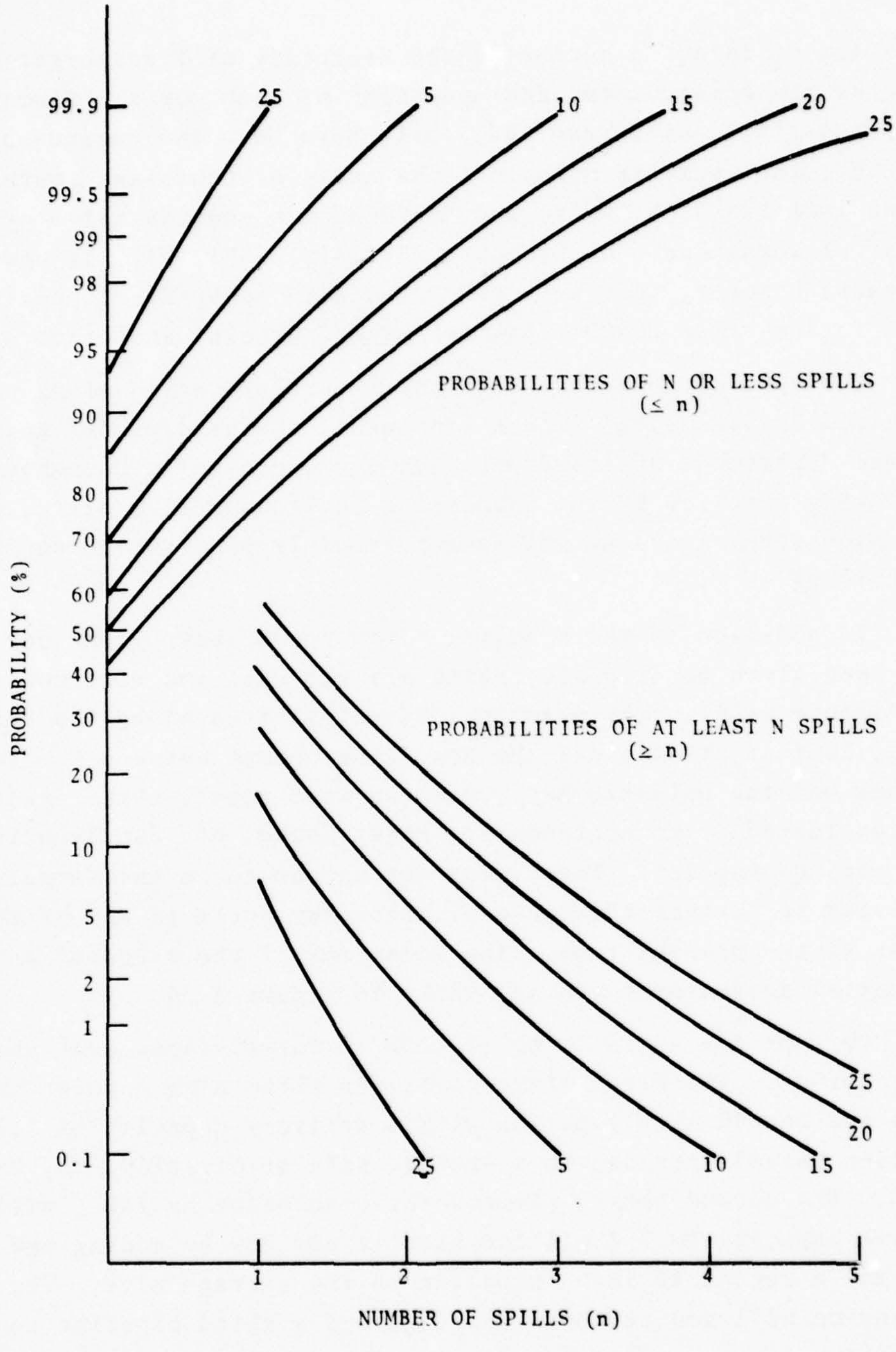

FIGURE 3-25. PROBABILITIES OF SPILLS > 50,000 GALLONS FROM OUTER CONTINENTAL SHELF OIL PRODUCTION AS A FUNCTION OF YIELD IN MILLIONS OF TONS

Port Act of 1974, to authorize the Secretary of Transportation to license the construction and operation of such ports. Since the Deepwater Port Act became law, there have been two serious proposals -- LOOP, Inc. some 18 miles off the coast of Louisiana south of Grand Isle (28°53'N, 90°N) and SEADOCK, Inc some 26 miles off the coast of Texas south of Freeport (28°28'N, 95°12'W). It now appears, however, that only LOOP is likely to be developed in the near future since SEADOCK has met with financial and other problems.

The applications for these ports were processed along with the required Environmental Impact Statements (References 3-7 and 3-15) by the Department of Transportation and approved in December 1976. Following a review by the Council on Environmental Quality, the licenses were signed by the Secretary of Transportation on January of 1977.

In addition to the specific sites noted above, consideration has been given to deepwater ports off the east and west coasts (Reference 3-14). The principal potential area along the east coast is that stretch off the New Jersey coast between New York Harbor and the Delaware Bay. Off the west coast, three areas may be considered prime contenders: Puget Sound, off San Francisco and off Los Angeles. There does not appear to be any formal activity to advance the cause of deepwater ports in any of these areas at the present time. The locations of the proposed and potential deepwater ports are shown in Figure 3-26.

Current plans are to build LOOP in three stages over an 11 year period. The first stage calls for three single point moorings and one 48 inch pipeline with a delivery capacity of 1.4 million barrels per day to a storage site at Clovelly, LA, by 1980. The second phase, planned for completion by 1982, will increase capacity to 2.4 million barrels per day by adding one mooring and a second 48 inch pipeline to the storage site. The final expansion will add two more moorings and a third pipeline to the Clovelly site for a total capacity of 3.4 million barrels per day by 1988. If constructed, SEADOCK would have an ultimate capacity of some 4 million barrels per day.

FIGURE 3-26. EXPECTED LOCATIONS OF DEEPWATER PORTS

Spill risk analyses for the LOOP and SEADOCK deepwater ports were included in the above-referenced Environmental Impact Statements prepared for the license applications. Spill rates were determined from these analyses as a function of throughput volume. These data were then processed in the manner of Section 3.3.1.1 to produce the spill probabilities summarized in Figure 3-37. The throughput volumes shown here in millions of tons correspond to the annual totals for the stated capacity values in millions of barrels per day, e.g., the annual throughput at 2.4 million barrels per day is some 130 million tons.

It should be noted that the same analysis has been applied in both the LOOP and SEADOCK proposals. Because of the similarity of operation, one could expect a similar threat from the potential deepwater ports. The expected spill rate for the overall operation of LOOP and SEADOCK is some 0.0027 spills $\geq$ 50,000 gallons per million tons of throughput volume -- about an order of magnitude less than that derived for the overall study area in Section 3.3.1.1. Thus, if all waterborne petroleum movements were funneled through deepwater ports at the 1977 level of 775 million tons, the expected number of spills $\geq$ 50,000 gallons would be about 2 per year, about one-tenth that estimated from the data of Section 3.3.1.1.

3.4.6 Lightering

A further alternative to enlarging and deepening of U.S. ports has been the implementation of the operational procedure known as "lightering". In this procedure portions of the petroleum cargo are removed from the oversized vessel at sea to lessen its draft to permit entry into port with a reduced cargo. In some instances all of the cargo is off-loaded in the lightering process and the prime mover (VLCC) never enters a U.S. port. Lightering operations have become commonplace off the West and Gulf coasts.

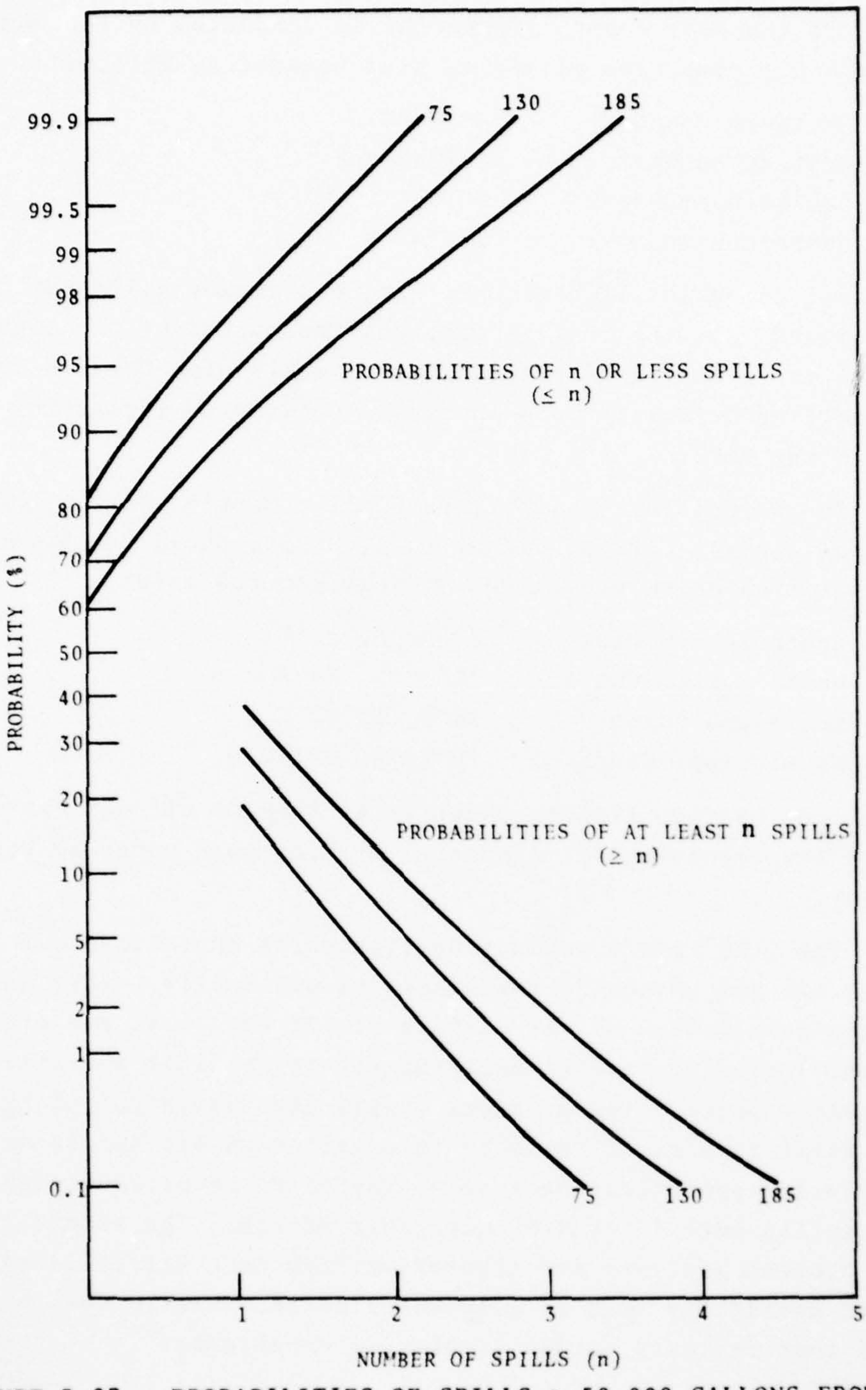

FIGURE 3-27. PROBABILITIES OF SPILLS ≥ 50,000 GALLONS FROM DEEPWATER PORT OPERATION AS A FUNCTION OF THROUGHPUT AND MILLIONS OF TONS

Off the West coast, lightering is conducted by the Shell and Chevron Oil companies within an area bounded as follows:

Northern boundary:	33°20'N
Western boundary:	118°40'W
Southern boundary:	32°40'N
Eastern boundary:	117°40'W

Both oil companies lighter underway, but employ different control techniques. In the Shell operation, the master of the lightering vessel is in charge of all maneuvers, while with Chevron the controlling authority is a specially designated lightering master aboard the VLCC.

In the Gulf of Mexico, some 9 oil companies (Arco, Chevron, Coastal States, Correo, Exxon, Gulf, Mobil, Shell and Texaco) conduct lightering operations in four general areas:

South Texas Coast	27°30'N, 97°W
North Texaco Coast	28°30'N, 94°W
Louisiana Coast	28°N, 89°30'W
Mississippi Coast	29°30'N, 88°30'W

Shell and Chevron lighter underway as they do off the West coast, while the remaining oil companies lighter both underway and at anchor.

The ULCC/VLCC's conducting lightering operations off the U.S. Coast are not immune to the danger of oil spills. They are exposed to the same causes of vessel-related oil spills as are other tank ships, including traditional transfer-to-terminal operations and deepwater ports. Two problems complicate assessment of this risk. The first is lack of reliable information on oil spills during lightering operations because no reporting requirement exists for oil spills outside of U.S. navigable waters. The second is that the present analyses for lightering have been extrapolated from other operations such as deep water ports. Little work has been done that reflects actual lightering experience.

Intuitively it would seem that the risk of smaller operational spills would be somewhat greater for lightering than for Deepwater Ports and the risk of larger catastrophic spills would be the same or slightly greater. However, no reliable data exist to bear out these speculations. While Deepwater ports seem to offer some significant advantages from safety, economic and environmental standpoints, the present lack of such facilities, and the long lead time for their construction, indicate that lightering will continue in U.S. coastal waters from some time to come.

3.5 ISSUE OF CONCERN

There are several issues of immediate concern which may alter the current situation and change the oil spill threat potential in one or more areas. These issues are discussed in depth in Reference 3-16 and summarized briefly here as they pertain to the exposure variable (throughput) used in this analysis.

3.5.1 Disposition of Alaskan Crude

The limited refinery capacity of the West coast, coupled with the inability of some refineries to process Alaskan crude oil because of its relatively high sulfur content, has resulted in a West coast surplus of some 500,000 barrels per day of Alaskan crude. By 1982, this surplus could be as high as 900,000 barrels per day. The question of the disposition of this surplus focuses on the logistics of bringing it to where it is most needed -- the major oil refining and distribution network of the eastern half of the contiguous U.S. Several proposals have been made to this end. The major alternative transportation systems for eastward movement of Alaska crude are shown schematically in Figure 3-28 (Reference 3-16). The individual alternatives shown are discussed briefly below.

The PACTEX pipeline proposal calls for the construction of a new tanker terminal at the Port of Long Beach, California for tankers up to 165,000 DWT. This terminal would be connected to an existing 800 mile, 42 inch natural gas pipeline which would be modified to carry crude in an easterly direction. Some 227 miles

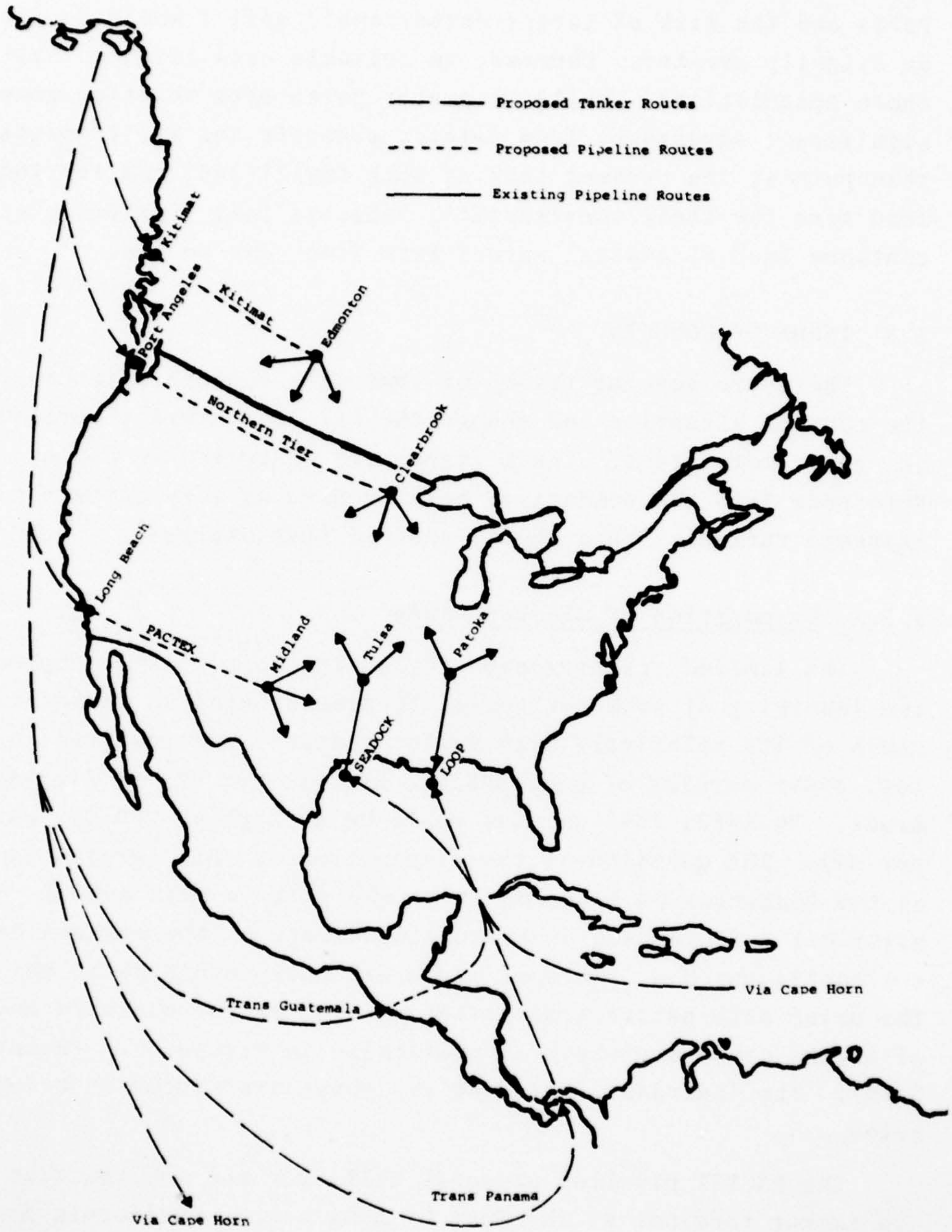

FIGURE 3-28 ALTERNATIVE TRANSPORTATION SYSTEMS FOR ALASKA CRUDE

of new pipeline would be added at the eastern end to carry the crude to Midland, Texas, where it would enter the crude oil distribution system that emanates from West Texas. Some 500,000 or more barrels per day would be carried eastward under this proposal.

The Northern Tier Pipeline proposal would require the construction of a new tanker terminal at Port Angeles near the entrance to Puget Sound where there is sufficient depth for tankers up to 300,000 DWT. A 40 to 42 inch pipeline would be constructed through the states of Washington, Idaho, Montana, North Dakota, and terminate at Clearbrook, Minnesota. This line would connect with existing pipelines along the way to serve refineries in the Rocky Mountain and Mid-Central States. At Clearbrook, connections with existing pipelines would extend the oil distribution to the Upper Mid-West and the refining center in the Great Lakes area. The initial capacity of the pipeline of some 700,000 barrels per day would ultimately be increased to some 940,000 barrels per day.

The Kitimat Pipeline proposal would require the construction of a tanker terminal at Kitimat, British Columbia, capable of handling tankers up to 320,000 DWT and a 753 mile 36 inch pipeline through which the Alaskan crude would be delivered to Edmonton, Alberta. From this terminus, the crude would be distributed to Montana, North Dakota, Minnesota, Wisconsin and the Great Lakes region. The design capacity of this proposal is some 400,000 barrels per day.

Several direct delivery by tanker alternatives to pipeline transportation have been considered by the petroleum industry. These include routings via LOOP, SEADOCK, Trans-Panama, Trans-Guatemala, and Cape Horn. However, the transport of oil by tanker from Valdez to ports in the Gulf of Mexico is seen by the petroleum industry as a costly, short-term expedient. Tankers of up to 65,000 DWT can pass through the Panama Canal fully loaded and larger vessels (up to some 90,000 DWT) can use the Canal if only partially loaded. Larger tankers would have to be routed via Cape Horn or off-loaded into smaller tankers off the western entrance to the Canal, neither of which is attractive from the standpoint of

transportation cost. As a compromise, two related proposals have been made, both of which would require the use of relatively short pipelines across the Central American isthmus. One calls for the construction of a U.S. navy pipeline running parallel to the canal, both to be supplied via deepwater terminals on the Pacific side of the isthmus. The Guatemala proposal is considered politically vulnerable and has little support within the industry. The use of the Navy pipeline across Panama is unlikely because the U.S. has an agreement with Panama not to implement any mode of transport that would compete with the canal.

It would thus appear that one or more of the pipeline proposals -- PACTEX, Northern Tier, and/or Kitimat -- will serve as the long term solution to the Alaskan crude problem. Of these, the Kitimat proposal does not affect the study area, the Northern Tier proposal affects deepwater terminal operations (Section 3.4.5) in the area about Puget Sound only, while the PACTEX proposal increases the spill potential from transient tankers (Section 3.4.4) throughout most of the length of the West coast and from deepwater terminal operations (Section 3.4.5) in the Long Beach, California area.

If the direct tanker alternatives are used in the short term, the entire West coast will be exposed to the transient tanker threat (Section 3.4.4) and the threat from deepwater port operations (Section 3.4.5) would be shifted to the Gulf of Mexico.

3.5.2 Florida Natural Gas Pipeline Conversion

In 1974 the Florida Gas Transmission Company applied to the Federal Energy Regulatory Commission for permission to convert a surplus natural gas pipeline to carry petroleum products currently carried by water from Texas and Louisiana to Florida. If approved, the conversion would permit an initial flow of some 200,000 barrels of petroleum per day with an ultimate capacity of 350,000 barrels per day. At the initial rate, the annual throughput would be some 12 million tons per year or about 75% of the nominal total volume of petroleum carried annually by vessels in that trade. The higher

rate far exceeds the annual waterborne throughput.

This proposal has met with considerable opposition from the independently owned U.S. flag tanker industry and from seafarer's unions. The issue is expected to be resolved by a decision of the Federal Energy Regulatory Commission by mid-1978. If approved, this diversion of petroleum throughput from waterborne commerce could significantly lessen the oil spill potential from such sources in this area.

3.5.3 Petroleum Imports

The U.S. dependency on foreign petroleum has increased markedly over time, and this trend is expected to continue into the future as projected in Table 3-3 (Reference 3-17). With the possible exception of the Mexican supply, the only way this petroleum can be transported is by tanker; primarily to ports in the New York, Philadelphia and Western Gulf of Mexico areas (Reference 3-16). Increased imports (throughputs) will increase the threat of spills from transient tanker movements along the coast (Section 3.4.4) and from operations about the domestic destinations.

TABLE 3-3 PROJECTED PETROLEUM IMPORTS THOUSANDS OF BARRELS PER DAY

Source	1977	1980	1985	1990
South America/Caribbean	1300	1300	1250	1150
Mexico	150	350	700	1250
West Africa	1200	1150	1200	1250
North Africa	1000	1150	1200	1250
Western Europe	-	100	500	500
Indonesia/Southeast Asia	630	810	850	950
Persian Gulf	3655	5485	6100	6600
	7935	10345	11800	12900

To realize the economic advantages available, much of this foreign oil is expected to be transported by very large vessels requiring the use of deepwater ports or lightering operations. The use of deepwater ports with pipelines to shore would minimize the threat (Section 3.4.5). Lightering operations, while inherently of minimal threat (Section 3.4.6), will necessitate the entry into port of a number of smaller vessels in much the manner as the current situation, but with increased density and, hence, threat (Sections 3.4.1 and 3.4.2). If, for some reason, very large vessels are not used and the transport picture becomes an extension of the current situation, the threat will likewise become an extension of the current experience (Sections 3.4.1 and 3.4.2).

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4. MASSIVE SPILL POTENTIAL

The Presidential goal of an adequate response within six hours to a spill of up to 100,000 tons of oil requires the U.S. Coast Guard to be prepared to offload or recover massive amounts of oil spilled in U.S. coastal waters. In order to meet this requirement it is necessary to estimate the size, number, location and type of potential massive spills in U.S. waters in the next decade. Of prime importance is the expected total discharge and discharge rates from massive spills, for they affect the amount and location of equipment required to cope with the spill. Also of importance is the nature of the incident, the type of oil involved, and the environmental conditions immediately after the incident. Ideally, one would like to project:

1. Type of incident (or series of incidents)
2. Probable locations
3. Type of oil involved
4. Total quantity of oil involved
5. Quantity of oil discharged
6. Time profile of oil discharge rate
7. Environmental conditions during and after the incident.

The type of incident is of interest because it is often a clue to the other items, and because certain types of incidents affect recovery efforts directly. For example, fires will reduce the amount of oil that must be recovered; explosions can hamper offloading operations; groundings have a different discharge rate profile from collisions.

The probable locations of possible future massive spills, of course, strongly influences equipment placement. While it is not possible to pinpoint such locations, nor estimate the probability of occurrence of a massive spill at a specific point, it may be

possible to locate general areas along the U.S. coast that are more likely than others to experience a massive spill.

The type of oil involved in a massive spill affects the amount and type of recovery equipment required. It is relatively easy to predict oil type because most incidents of interest (as will be seen) involve crude or residual oils.

The quantity of oil involved, the amount spilled, and the discharge rates are important in the determination of equipment levels and locations. Offloading requirements are determined by the total amount onboard, less the amount discharged up to the time of completion of offloading.* Skimming requirements are derived from the discharge rate profile. In the case of offshore platform blowouts the total quantity of oil involved is indeterminate, for practical purposes, but this presents no difficulty because offloading need not be considered in such cases.

Before describing the method adopted to make the above estimates, the term 'massive spill' needs to be made more precise. For the purposes of data gathering, an historic massive spill is taken to be any harbor, coastal or open sea incident in which over 3,000 tons** of petroleum or its products was actually spilled. This lower limit is set at only 3% of the nominal for a massive spill so that a larger number of incidents will be eligible for study. The assumption is that many of these smaller incidents had the potential for a much larger spill and hence can contribute to our knowledge of possible future massive spills of the 100,000 ton variety.

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*This amount assumes that <u>all</u> the oil remaining on board may need to be offloaded. In a given spill situation, the actual amount offloaded also depends on salvage calculations and stability considerations.

**3,000 metric tons corresponds to 924,000 U.S. gallons at the world-average density of crude, 308 gallons per ton. (Reference 4-1, p.440.) For simplicity a value of 300 gallons of oil per ton will be employed in this Section.

4.1 METHOD AND ASSUMPTIONS

The description of possible accidental events that may occur as much as ten years in the future necessarily requires several assumptions, which will limit the reliability of the results. The method of developing estimates of items 1 through 7 is as follows:

1. The types of accident that have produced massive spills are determined from a review of available information concerning historic massive spills. It is assumed that the nature and relative frequency of these incidents will persist into the 1980-1990 time frame. This assumption will most likely lead to an over estimate of the frequency of spills of the types selected for two reasons: (a) it does not allow for improved vessel and offshore production technology and (b) it does not allow for improved regulation, traffic control and safety practices. It has been estimated that from 25 to 78 percent of rammings can be prevented by measures that range from regulations currently proposed for shipboard equipment to more complex shore-based systems (Reference 4-2). However, VLCC's are likely to be less affected by preventive measures than other vessels since such devices as LORAN, on-board radar and improved communications are already common on VLCC'S. It is due to this uncertainty about the effectiveness of preventive measures for VLCC's that the relative frequency of massive spills involving these vessels has not been reduced for future projections.

2. Estimates of typical average outflow rates are made by a analyzing reports of seven selected massive vessel spills.

3. Projections are made of the more likely locations of massive spills in U.S. coastal waters in the 1980-1990 time period, based on estimated shifts of U.S. coastal tanker traffic and expected OCS development

4. Finally, scenarios are constructed describing the time-sequence of events for three typical massive spills. These scenarios will be employed later to determine the additional levels of equipment and logistic support required to meet a massive spill threat.

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DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
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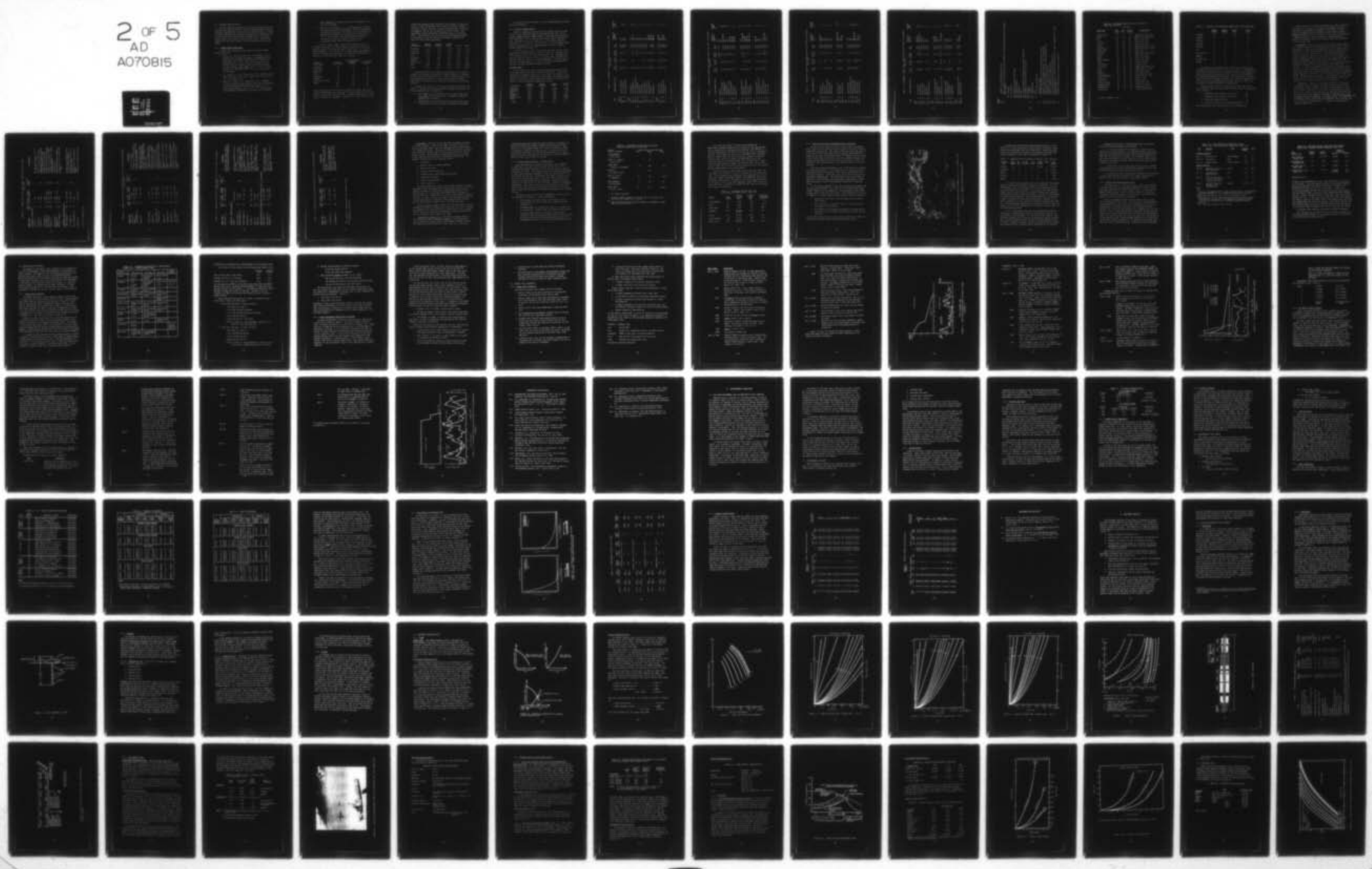

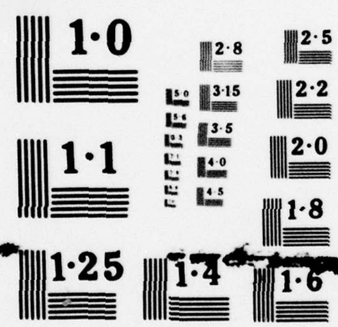
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4.2 HISTORIC MASSIVE SPILLS

Historic data were examined for actual and potential massive spills of two general types (a) spills originating from offshore platforms and pipelines, and (b) spills from tank ships. In order to obtain adequate data, worldwide incidents were considered and no time limits were placed on the incident date. The present section deals with historic massive tanker spills, and the next section will deal with historic offshore pipeline and platform spills.

4.2.1 Tanker Spills (Overview)

At least four studies have been made of historic tanker spills worldwide.

1. Keith, V.F. and Porricelli, J.D., "An Analysis of Oil Outflows Due to Tanker Accidents," Proceedings of the Conference on Prevention and Control of Oil Spills, Washington, D.C., 1973. This is an extension of an earlier paper (Porricelli, Keith and Storch, Tankers and the Economy, Trans. SNAME, 1971). A total of 269 incidents in 1969 and 1970, of all sizes of outflows, are discussed.
2. J.J. Henry Co., Inc., "An Analysis of Oil Outflows Due to Tanker Accidents, 1971-1972," Report CG-D-81-74 for the U.S. Coast Guard, 1973.
3. Card, J.C., Ponce, P.V., and Snider, W.D., "Tankship Accidents and Resulting Outflows, 1969-1973," Proceedings of the Conference on Prevention and Control of Oil Pollution, Washington, D.C., 1975. This study examined 3,183 tankship involvements of vessels over 3,000 DWT.

Some breakdown by location is given, but outflows of all sizes are included.

4. Byer, A.H., and Painter, L.J., "Estimating the Potential for Future Oil Spills from Tankers, Offshore Development and Onshore Pipelines," Proceedings of the Conference on Prevention and Control of Oil Pollution, Washington, D.C., 1977. In this paper, the preceding three papers are re-analysed, with the inclusion of data on Outer Continental Shelf spills and pipeline spills.

A review of these studies reveals that further analysis of the data is necessary to obtain adequate information on historic massive spills of the type that will be dealt with by U.S. Coast Guard equipment. Of the four, that of Card, Ponce, and Snider is the most relevant to our purposes. Of the 3,183 involvements of vessels over 3,000 DWT they found the following:

TYPE OF INVOLVEMENT	% OF ALL INVOLVEMENTS	% OF IMPROVEMENTS PRODUCING OUTFLOW	% OF OUTFLOW PRODUCED
Breakdown	11	2	3
Collision	24	28	18
Explosion	3	7	9
Fire	6	4	0.3
Grounding	25	27	22
Ramming	15	10	1
Structural Failure	16	21	32
Other	0.2	1	4
	100	100	100

Thus groundings and collisions each account for about one-fourth of all involvements, but since each collision produces two involvements (if both were over 3,000 DWT) it appears that the most common type of accident is grounding. Further, it is seen from the second

column that groundings and collisions also account for about one-fourth of these involvements that result in outflow. However, structural failures are also a large percentage (21%) of outflow involvements, and in fact, produce 32% of all outflow. This percentage is more than either groundings (22%) or collisions (18%). The reason for this is seen in the following percentage distributions of the 452 outflow involvements, adopted from Table 8 of Card, Ponce and Snider:

TYPE OF INVOLVEMENT	HARBOR AND PIER	HARBOR ENTRANCE	COASTAL AREAS	AT SEA	TOTAL
Breakdown	0.2%	0.2%	1.1%	0.7%	2.4%
Collision	10.2	5.0	10.0	2.0	27.2
Explosion	2.0	0.0	1.3	3.3	6.6
Fire	2.6	0.0	0.2	0.9	3.7
Grounding	6.2	8.8	11.7	0.0	26.7
Ramming	7.3	1.1	0.9	0.4	9.7
Struct. Fail.	3.8	0.9	1.5	14.2	19.5
Other	0.2	0.0	0.4	0.2	0.8
Total	10.6	21.9	16.6	27.2	100.0

Fourteen percent of all outflow involvements are structural failures at sea, where the result is almost invariably a sinking of the vessel with its entire cargo. Such incidents, however, are often beyond the capability of any pollution control efforts, particularly if they occur very distant from shore and with great rapidity.

To apply the results of Card, Ponce and Snider to the massive spills of interest to pollution response equipment deployment, two further questions must be answered:

- What happens to the distribution of incident types when only spills over 3,000 tons are considered, instead of tankers over 3,000 DWT?
- What happens to the distribution of incident types when incidents more than 50 n. miles from shore are excluded?

To answer these two questions, a brief supplementary investigation was undertaken.

4.2.2 Historic Tanker Spills

Table 4-1 summarizes some 68 historic tanker spills of 3,000 tons of oil or more that took place worldwide from 1967 to the present (TORREY CANYON to AMOCO CADIZ). These data were extracted from References 4-3, 4-5, and 4-6 and checked against Reference 4-4. Although the list is extensive, it is not known just how complete it is. It may be said only that it is more complete than any of the component lists, except perhaps for Lloyd's Weekly Casualty Reports, Reference 4-4.

Of the 68 spills listed, 25 occurred more than 50 n.mi. from the nearest coastline and are listed in Table 4-2. Almost all of these vessels sank at sea with their entire cargo. Although they may be classed as massive spills by the 3,000 ton criterion, oil recovery from such spills is usually impossible. For this reason they are not representative of the spills upon which pollution response equipment deployment should be based.

Incident Types

The 68 spills over 3,000 tons have been broken down by type of incident and by location, as shown in Table 4-3. In order to compare this breakdown with that of Card, Ponce and Snider, it is necessary to combine strandings with groundings, and flooding/sinking with structural failure. When this is done, one obtains from Table 4-3 the following percentage distribution:

INVOLVEMENT	HARBOR INTERIOR	HARBOR ENTRANCE	COASTAL AREA	>50 NM AT SEA
Breakdown	0.0%	1.5%	0.0%	0.0%
Collision	0.0	1.5	10.3	0.0
Explosion	0.0	0.0	0.0	2.9
Fire	0.0	0.0	1.5	1.5
Grounding	2.9	10.3	27.9	0.0
Ramming	0.0	0.0	0.0	0.0
Struct. Fail.	0.4	0.4	6.3	29.8
Other	0.0	0.0	0.0	2.9
Total	3.3	13.6	46.0	37.1

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS
1967-1978

DATE	VESSEL NAME/YR BUILT	DWT* K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
1967							
March 18	Torrey Canyon/1959	118.	110.	110.	Crude	STD	C
Sept. 6	R.C. Stoner/1943	18.	17.	17.	Light	STD	HE
Oct. 25	Giorgio Fassio/1954	19.	19.	19.	Crude	SNK	S
1968							
Feb. 4	Sivella/1963	63.		5.	Crude	GND	C
March 3	Ocean Eagle/1953	19.	18.	7.-8.	Crude	STD,(1)	HE
March 8	Gen. Colocotronis/1955	18.		5.	Crude	STD	C
April 29	Esso Essen/1960	51.		4.-15.	Crude	GND	C
May 8	Andron/1953	16.		16.	Crude	SNK	S
May 18	Chunchi/1946	7.	7.	7.	Heavy	STD	C
June 14	World Glory/1954	46.	46.	46.	Crude	STF	C
July 25	Sofia M./1949	13.		6.	Crude	STD	C
Nov. 3	Spyros Lemos/1953	20.	20.	20.	-	STF,SNK	C
Nov. 5	Keo/1949	30.	30.	30.	Heavy	STF,SNK	S
Nov. 25	Pacocean/1949	30.	30.	30.	Crude	STF,SNK	S
1970							
Jan. 6	Sofia P./1954	19.	18.	18.	Light	STF,SNK	S
Jan. 14	Albacruz/1954	20.	20.	20.	Crude	SNK	S
Jan. 31	Gezina Brovig/1951	16.	16.	16.	Light	EXP,SNK	S
Feb. 4	Arrow/1948	18.	16.	11.	Heavy	STD	C

*K tons = thousands of tons

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS (Continued) 1967-1978

DATE	VESSEL NAME/YR BUILT	DWT K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
March 20	Othello/			60-100.	Crude	COL	C
April 17	Silver Ocean/1950	19.	18.	18.		STF	S
May 5	Polycommander/1965	50.	49.	.5-5.	Crude	STD, FRE, EXP	HE
June 1	Ennerdale/1963	49.	42.	41.	Light	GND	HE
Oct. 7	Anastasia J.L./1952	18.	18.	18.	Crude	SNK	S
Oct. 23	Pacific Glory/1966	78.	77.	4.-7.	Crude	COL, FRE	C
Dec. 28	Chryssi/1952	31.	31.	31.	Crude	STF, SNK	S
Dec. 27	Ragny/1951	17.	17.	17.	Light	STF, SNK	S
1971							
Jan. 18	Oregon Standard/1944	17.		3.	Heavy	COL	HE
Feb. 27	Wafra/1956	64.	40.	8./32(6)	Crude	BKD, STD, SNK	C
March 29	Texaco Oklahoma/1958	35.	35.	35.	Heavy	STF, SNK	S
July 30	Alkis/1955	20.	19.	19.	Crude	STF, SNK	S
Nov. 30	Juliana/1958	19.	18.	4.	Crude	GND, STD (7)	HE
1972							
Jan. 28	Golden Drake/1950	32.	31.	31.	Crude	EXP, SNK	S
Apr. 1	Giuseppe Giulietti/1954	27.	26.	26.	Light	SNK	S
June 11	Trader/1957	34.	34.	34.	Heavy	SNK	S
Agu. 21	Oswego Guardian/1968	97.	91.	10.	Crude	COL	C
Dec. 19	Sea Star/1968	120.	100.	100(10)	Crude	COL, FRE, EXP	C
April 27	Silver Castle/		18.	<3.	Crude	COL (11)	C

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS (Continued) 1967-1978

DATE	VESSEL NAME/YR BUILT	DWT K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
1973							
Feb. 20	Nelson/1957	21.	20.	20.	Light	STF,SNK	S
March 18	Zoe Colocotroni/			5.	Crude	STD	C
June 10	Napier/1957	39.	38.	19.	Crude	STD	C
June 18	Cosmos Pioneer/1951	14.	13.	13.	Light	STD	C
Aug. 5	Dona Marika/1954	11.		3.	Light	GND	C
Dec. 21	Jawachta/1963	55.	20.	>3.	Crude	STF	C
1974							
July 23	Theodorus V/1954	21.	20.	20.	Crude	FRE,EXP,SNK	S (9)
Aug. 10	Metula/1968	207.	196.	52.	Crude	STD	C
Sept. 26	Transhuron/1945	20.	18.	5.	Heavy	BKD,STD	C
1975							
Jan. 6	Showa Maru/1973	238.	238.	4.	Crude	STD	C
Jan. 10	British Ambassador.1958	45.	44.	44.	Crude	SNK	S
Jan. 2-21	Oswego Patriot/1965	99.		5.	Crude	STF	(8)
Jan. 29	Jakob Maersk/1966	88.	88.	(4).	Crude	GND,EXP,FRE	HI
March 26	Tarik Ibn Ziyad/	119.	104.	10.	Crude	GND	HI
April 4	Spartan Lady/1955	21.	20.	20.	Crude	STF,SNK	S

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS (Continued)
1967-1978

DATE	VESSEL NAME/YR BUILT	DWT K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
1976							
Feb. 5	St. Peter/1957	34.	34.	34.	Crude	FRE,SNK	C
May 12	Urquiola/1973	109.	100.	15.(5)	Crude	GND,EXP,FRE	HE
July 28	Cretan Star/1955	30.	29.	29.	Crude	MSG,SNK	S
Oct. 5	Sealift Pacific			4.	Crude	GND	C
Oct. 14	Bohlen/1961	11.	11.	3.	Crude	SNK	C
Dec. 16	Argo Merchant/1955	28.	28.	28.	Heavy	STD	C
1977							
Jan. 18	Irenes Challenge/1956	34.	10.	10.	Crude	STF,SNK	S
Jan. 1-4	Grand Zenith/1953	31.	29.	29.	Heavy	MSG,SNK	S
Feb. 7	Borag/1958	35.		10.	Heavy	STD	C
Feb. 23	Hawaiian Patriot/1965	99.	90.-95.	90.-95.	Crude	STF,EXP,SNK	S
May 27	Caribbean Sea/1958	30.	30.	30.	Crude	SNK	S
Oct. 30	Al Rawdatain/1976	328.		6.	Crude	BKD	HE
Dec. 16	Venoil/1973	326.	307.	23.	Crude	COL	C
Dec. 16	Vendet/1973	326.		3.	Heavy	COL	C
1978							
Jan. 14	Brazilian Marina/1974	318.		12.	Crude	GND	HE
March 17	Amoco Cadiz/1974	228.	220.	220.	Crude	BKD,STD	C

<u>NOTES</u>:

(1) Grounded, then stranded and broke in half.

(2) Codes as follows (the incident type used for analysis is underlined where more than one incident type is given)

STD = Stranded

COL = Collision

SNK = Sunk due to flooding, with cargo

GND = Holed in passage

EXP = Explosion

FRE = Fire

STF = Structural failure, including cracks and leaks through hull

BKD = Breakdown or mechnical failure, value leaks

MSG = Missing

(3) HI = In Harbor

HE = Harbor Entrance

C = Coast

S = 50 n. miles or more at sea

(4) 40-50,000 tons burned.
20-25,000 tons drifted to sea, and 15,000 tons drifted to shore

(5) Estimates of amount discharged vary from 5. to 15. thousand tons

(6) Bombed and sunk with 32,000 tons on board, after being towed to sea

(7) Dragged anchor, grounded, broke in two

(8) Leaked from Singapore to Los Angeles Harbor

(9) About 60 nautical miles due west of Cape Blanc, Africa

(10) Fires and explosions for 5 days may have burned off much of cargo. Remainder sank. Amount spilled not known.

(11) Insufficient data obtained - not included in statistics

TABLE 4-2. WORLDWIDE TANKER SPILLS 50 N.MILES OR MORE FROM THE COAST

1967-1978

VESSEL NAME	DWT K tons*	AGE Yrs	SPILLED K tons	INCIDENT TYPE
Giorgio Fassio	19.	13	19.	Engine Room flooded, Sunk
Andron	16.	15	16.	Engine Room flooded, Sunk
Keo	30.	25	30.	Broke in two, Sunk
Pacocean	30.	20	30.	Broke in two, Sunk
Sofia, P.	18.	16	18.	Broke in two, Sunk
Albacruz	20.	16	20.	Engine Room flooded, Sunk
Gezina Brovig	16.	19	16.	Engine Room explosion, Sunk
Silver Ocean	19.	20	18.	Broke in two
Anastasia	18.	18	18.	Engine Room flooded, Sunk
Chryssi	31.	17	31.	Broke in two, Sunk
Ragny	17.	19	17.	Broke in two, Sunk
Texaco Oklahoma	35.	13	35.	Broke in two, Sunk
Alkis	20.	16	19.	Cracked and Sunk
Golden Drake	32.	22	31.	Explosion, Sunk
G. Giulietti	27.	18	26.	Engine Room flooded, Sunk
Trader	34.	15	34.	Engine Room leak. Sunk
Nelson	21.	16	20.	Hull cracked, Sunk
Theodorus V	21.	20	20.	Fire, Explosion, Sunk
British Ambassador	45.	17	44.	Engine Room leak, Sunk
Spartan Lady	21.	20	20.	Broke up, Sunk
Cretan Star	30.	21	29.	Missing, Sunk
Irenes Challenge	34.	21	34.	Broke in two, Sunk
Hawaiian Patriot	99.	22	99.	Broke in two, Sunk
Caribbean Sea	30.	19	30.	Engine Room leak, Sunk
Grand Zenith	31.	24	29.	Missing, presumed Sunk

*K tons = thousands of tons

TABLE 4-3. ANALYSIS OF 68 WORLDWIDE TANKER SPILLS OVER 3,000 TONS

	HARBOR INTERIOR	HARBOR ENTRANCE	COASTAL AREA	>50 NMI AT SEA
Stranding	0	3	15	0
Breakdown	0	1	0	0
Collision	0	1	7	0
Grounding	2	4	4	0
Explosion	0	0	0	2
Fire	0	0	1	1
Structural Fail.	0	0	3	12
Ramming	0	0	0	0
Flooding, Sunk	0	0	1	8
Missing	0	0	0	2

The effects of considering only spills over 3,000 tons, and separating out those beyond 50 n.mi. off the coast is now apparent: (1) harbor collisions are not a prominent cause of large spills, (2) harbor and coastal explosions and fires are even less prominent, (3) coastal groundings become the most significant cause of massive spills at 33%, (4) rammings disappear, (5) structural failures at sea are the second most prevalent incident type (27%), and, (6) the number of harbor incidents is insignificant.

The most likely types of incidents, then, when only spills over 3,000 tons and less than 50 n.mi from the coast are considered, are as follows:

- Groundings and Strandings on the coast - - 33%
- Groundings and Strandings in harbors - 9%
- Collisions along the coast - 9%
- Structural Failures plus Floodings/Sinkings - 6%

The remaining 43% occur more than 50 n.mi. from the coast.

The next step is to analyze the harbor and coastal incidents (See Table 4-4.) Thirty six of the 42 involvements could be classified as groundings, strandings, or collisions. As far as could be determined from the references the JULIANA and POLY COMMANDER grounded and then stranded, so that their classification is somewhat in doubt. The remaining six involvements were primarily structural failures or floodings that occurred within 50 n.mi. of the coast.

Groundings: (24%) Five of the ten incidents listed (Table 4-4) occurred within or at the entrance to a major harbor; of the remaining six, three occurred within 25 n.mi. of a major harbor. Therefore, it seems that about half of historic groundings were within 25 n.mi. of a major harbor. This estimate must be considered approximate because of the smallness of the sample. A typical grounding occurs as the vessel is exiting or entering the harbor (JACOB MAERSK, OCEAN EAGLE, TARIK IBN, URQUIOLA). Not uncommonly, the grounding is followed by a fire or explosion which reduces the amount of oil to be recovered, but hampers its recovery. If the POLY COMMANDER is considered a grounding, then three out of eleven groundings would have resulted in explosion or fire, while none of the seventeen strandings would have so resulted, except for fires deliberately set in the cases of the NAPIER and WAFRA. The data suggest, therefore, that grounding are more likely to lead to explosion or fires than are strandings. Again, the smallness of the sample prevents any firm conclusion.

Strandings: (43%) By far the most prevalent incident type in the data is the stranding. Of these, almost 90% are coastal (although the WAFRA and BORAG were not far from harbors). It is not possible to generalize as to causes of strandings from these data, since a full investigation was not undertaken in every case. The three causes most suspected, however, are navigational error, pilotage error, and breakdown. The TORREY CANYON, POLY COMMANDER, ZOE COLOCOTRONI, METULA, SHOWA MARU, ARGO MERCHANT were strandings due to navigational or pilotage error. Examples of breakdown are WAFRA and AMOCO CADIZ.

TABLE 4-4. TANKER SPILLS OVER 3,000 TONS WITHIN 50 N.MI. OF COAST
1967-1978

VESSEL (AGE)	K tons* DWT	K tons Spilled	% Cargo Spilled)	Location (1) Code	Description
Groundings - ten incidents					
SIVELLA (5)	63.	5. Crude		C	Hit rock off Mouille Pt, 1/2 mile off Cape Town, S. Africa
ESSO ESSEN (8)	51.	4. Crude		C	Hit reef off Cape of Good Hope
JULIANA (13)	19.	4. Crude		HE	Dragged anchor, grounded, stranded outside Niigata Harbor, Japan
DONA MARIKA (19)	11.	3. Light		C	Lindsway Bay, Wales, England
JACOB MAERSK (9)	88.	40. Crude	(45%)	HI	Grounded entering Leixos, Portugal*
TARIK IBN ZIYAD	119.	10. Crude	(10%)	HI	Grounded in Rio de Janeiro harbor
URQUIOLA (3)	109.	15. Crude	(15%)	HE	Grounding, explosion, fire, sinking in LaCoruña, Spain*
SEALIFT PACIFIC		4. Crude		C	Cook Inlet, AK
ENNERDALE (7)	49.	41. Light	(84%)	HE	Exiting Port Victoria, Seychelles
BRASILIAN MARINA (2)	318.	12. Crude		C	Hit rock, about 25 mi. south of Rio de Janeiro
Strandings - eighteen incidents					
TORREY CANYON (8)	118.	110. Crude	(100%)	C	Grounded, then stranded on shoals off S.W. Cornwall, England
R.C. STONER (24)	18.	17. Light	(100%)	HE	Stranded on reef near entrance to harbor, Wake Island
GEN. COLOCOTRONIS (13)	18.	5. Crude		C	Stranded on reef off Eleuthera I, Bahamas
CHUNCHI (22)	7.	7. Heavy	(100%)	C	Stranded off S. Coast of S. Korea

* K tons = thousands of tons

TABLE 4-4. TANKER SPILLS OVER 3,000 TONS WITHIN 50 N.MI. OF COAST (Continued) 1967-1978

VESSEL (AGE)	K tons DWT	K tons Spilled	% Cargo Spilled	Location Code[1]	Description
SOFIA M (19)	13.	6. Crude		C	Off Coast of Colombia
ARROW (22)	18.	11. Heavy	(61%)	C	Cerebrus Rock, Chedabucto Bay, N.S.
POLYCOMMANDER (5)	50.	<5. Crude	(<10%)	HE	Grounded, fire and explosion, about 10 miles from Vigo, Spain*
WAFRA (25)	64.	8. Crude	(20%)	C	Broke down, taken in tow, line parted, drifted aground, holed, refloated; off Cape Agulkas (Cape Town) S.A. Towed 170 miles to sea and bombed, sunk
ZOE COLOCOTRONI		5. Crude		C	Stranded off Parraguerra, P.R., offloaded into ocean, refloated
NAPIER (16)	39.	19. Crude	(50%)	C	Stranded, set afire, off coast of Chile, near Folfo Corcovado*
COSMOS PIONEER (22)	14.	13. Light	(100%)	C	Stranded off cost of India
OCEAN EAGLE (15)	19.	7. Crude	(39%)	HE	Stranded and broke in two off El Moro Castle at entrance to San Juan harbor, P.R.
METULA (5)	207.	52. Crude	(27%)	C	Aground and stranded in Straits of Magellan
TRANSHURON (28)	20.	5. Heavy	(28%)	C	Stranded on Kiltan I., S.W. coast India
SHOWA MARU (2)	238.	4. Crude	(2%)	C	Stranded, in Straits of Singapore, offloaded 36 MT, refloated
ARGO MERCHANT (23)	28.	28. Crude	(100%)	C	Stranded 29 n.mi. S.E. of Nantucket
BORAG (19)	35.	10. Heavy		C	Stranded 10 n.mi. N of Tai-pei, Taiwan

TABLE 4-4. TANKER SPILLS OVER 3,000 TONS WITHIN 50 N.MI. OF COAST (Continued)
1967-1978

VESSEL (AGE)	K tons DWT	K tons Spilled	% Cargo Spilled	Location Code (1)	Description
AMOCO CADIZ (4)	228.	220. Crude	(100%)	C	Engine and rudder failure, taken in tow, line parted, drifted aground, brokeup near Portsal, Brittany Coast
Collisions - eight involvements					
OTHELLO		60-100. Heavy		C	Collided with KATALYSIA off Stockholm, Sweden
PACIFIC GLORY (4)	78.	4. Crude		C	Off St. Catherine's Pt., England
OREGON STANDARD (27)	17.	3. Heavy		HE	With ARIZONA STANDARD, Near Golden Gate Bridge, San Francisco
OSWEGO GUARDIAN (4)	97.	10. Crude	(11%)	C	With TEXANITA off Pt. Agulhas, Cape Town, S.A.
SILVER CASTLE				C	Collision with S.A. PIONEER off S. Africa coast
SEA STAR (4)	120.	<100. Crude	(<100%)	C	Collided with NORTA BARBOSA in Gulf of Oman. Sunk
VENOIL (4)	326.	23. Heavy		C	Collided with VENPET, 23 mi. off coast, S.W. of Port Elizabeth, South Africa
VENPET (4)	326.	3. Heavy		C	
Structural Failures or Sinkings due to Flooding or Fire - six incidents					
WORLD GLORY (14)	46.	46. Crude	(100%)	C	Broke in two off coast of South Africa, 65 miles EWE of Durbon
SPYROS LEMOS (15)	20.	20. (?)	(100%)	C	Broke up off Vigo, Spain
JAWACHTA (10)	55.	>3. Crude	(>15%)	C	Hull fracture, unreported cause off Swedish coast

TABLE 4-4. TANKER SPILLS OVER 3,000 TONE WITHIN 50 N.MI. OF COAST (Continued)

VESSEL (AGE)	K tons DWT	K tons Spilled	% Cargo Spilled	Location Code (1)	Description
BOHLEN (15)	11.	3. Crude	(27%)	C	Sunk off Brittany coast, about 45 n.mi. S.W. of Brest; most of cargo offloaded
ST. PETER (19)	34.	34. Crude	(100%)	C	Caught fire in engine room, sunk, 30 miles N.E. of Esniaraldes, Ecuador about 16 n.mi off shore*
AL RAWDATAIN (1)	328.	6. Crude	(2%)	HE	Leakage from broken valve outside Genoa harbor

(1) C = coastal, HI = harbor interior, HE = entrance to harbor.

(*) Indicates fire or explosion.

<u>Collisions</u>: (19%) Only one of the eight collisions occurred in or near a harbor. Three of the eight resulted in fire or explosion (although details were not obtained on the SILVER CASTLE/S.A. PIONEER collision). The most prominent location of collisions seems to be the southern tip of Africa, where 4 out of 8 involvements occurred. The influence of reduced visibility, and rules of the road have been discussed in References 4-7 and 4-8. In general, several factors are involved, such as

1. Visibility
2. Channel, route or fairway geometry
3. Rules of the road
4. On-shore vessel monitoring
5. Communications (shore/ship and ship/ship)
6. Shipboard navigation
7. Vessel size and speed
8. Traffic density.

Locations where these factors are favorable should, in theory, experience fewer collisions than locations where they are not. No attempt was made to correlate the present data with any of the above factors, but if one takes the VENPET-VENOIL incident as typical, then it is seen that (1) visibility was 2 miles (Reference 4-4, Jan. 9, 1978, p. 364), (2) vessel size and speed were such as to make maneuvering or stopping distances greater than 2 miles, and (3) the traffic is dense in the S. African Cape area.

To the collisions shown in Table 4-4, one may add that of the CORINTHOS and QUEENY at Marcus Hook, PA on Jan. 31, 1975. Although the CORINTHOS lost over 1600 tons of crude, most of it was burned in the fires that followed the explosions, so that less than 200 tons is recorded to have reached the water.

<u>Structural Failure et al</u>: (14%) These incidents appear to have mechanical and/or structural origins. In the majority of cases (OCEAN EAGLE, WORLD GLORY, SPYROS LEMOS, JAWACHTA, BOHLEN, ST. PETER) the vessels were 10 or more years old. Card <u>et al</u>

(Referenced above) have shown the sharp increase in incidence of structural failure for tankers between 10 and 20 years of age. When the six involvements above are viewed in relation to Table 4-2 above and Figure 16 of Ponce et al., it appears that these involvements are merely the coastal and harbor portion of widespread structural and mechanical failures that affected tankers of age 10-20 years in the 1967-1977 period.

4.2.3 Historic Massive Spills - Outflow Rates

Seven incidents were selected from Table 4-4 and analyzed in some detail in order to estimate the outflow rates. The selection was made on the basis of the size of the spill and the availability of data. The larger size spills were given preference in the selection because equipment levels are paced by spills of the 100,000 ton variety. Fortunately, the larger historic spills are also the better documented. The seven spills analyzed consisted of six strandings and one grounding. Adequate estimates could not be made for any of the collisions, because of inadequate information. This lack of data is possibly due to the fact that many of the collisions were attended by spectacular fires which made it difficult to observe or estimate the amount of oil reaching the water.

The seven spills are analyzed in Appendix B, and the results are summarized in Table 4-5. Some observations:

1. The minimum rates have little significance, and are included only to show the range of estimates within a single spill.
2. The AMOCO CADIZ far exceeded the other six incidents in all categories: minimum, mean, and maximum outflow rate.
3. The mean outflow rates are probably better design parameters than the maximum outflow rates because (a) they are more accurate and (b) sudden discharges can not be accommodated in real time by a practical skimming system.

TABLE 4-5. ESTIMATED OUTFLOW RATES FOR SEVEN SELECTED TANKER SPILLS, 1967-1978

NAME OF VESSEL, LOCATION	OUTFLOW RATE, TONS PER HOUR MIN.	MEAN	MAX.
POLYCOMMANDER, Vigo, Spain	-	6.	-
WAFRA, Pt. Agulhas South Africa	-	35.	-
SHOWA MARU, Straits of Singapore	5.0	106.	712.
URQUIOLA, La Coruña, Spain	-	170.	-
METULA, Straits of Magellan	14.	49.	186.*
ARGO MERCHANT, Off Nantucket	1.7	70.	**
AMOCO CADIZ Portsal, France	104.	611.	4,200.

– No estimate possible

* Excludes sudden discharge of 14,000 tons in an unspecified short period, probably 12-24 hours.

** About 13,000 tons were released suddenly on December 21 when the vessel split in two.

It is clear from Table 4-5 that even excluding the AMOCO CADIZ, average outflow rates in excess of 100 tons per hour can be expected from strandings and groundings (the URQUIOLA is the only grounding in the Table; the other six are all strandings). Further, since tankers of the size of the AMOCO CADIZ, (228,000 DWT) are common today and will be even more common in 1980-1990, there is every reason to include the AMOCO CADIZ spill when estimating historic worldwide tanker spill outflow rates. Therefore, the data certainly suggest that outflow rates of the order of 200 to 500 tons per hour have been characteristic of the largest massive tanker spills (60-150 Kgals/hour).

Table 4-6 shows the seven tanker spills with their DWT, outflow amount (oil burned or sunk not included) and the time of outflow. Five incidents were strandings not accompanied by fire or explosion: WAFRA, SHOWA MARU, METULA, ARGO MERCHANT, AMOCO CADIZ. One notices that the two strandings in which the vessel broke up on the spot by wave action (ARGO MERCHANT, AMOCO CADIZ) both took about 350 hours, although the average outflow rates were different by a factor of almost ten.

TABLE 4-6. ESTIMATED OUTFLOW TIMES FOR SEVEN SELECTED TANKER SPILLS, 1967-1978

VESSEL	DWT K TONS	AMOUNT SPILLED TONS	OUTFLOW TIME HRS	MEAN RATE OF OUTFLOW TONS/HR
POLYCOMMANDER	50.	1,050	168	6.25
WAFRA	64.	8,000	226	35.4
SHOWA MARU	238.	3,300	31	106.5
URQUIOLA	109.	50,000-60,000	312	170.
METULA	207.	54,000	1,092	49.
ARGO MERCHANT	28.	25,333	360	70.
AMOCO CADIZ	228.	220,000	348	611.

4.2.4 Spills on the Outer Continental Shelf (Overview)

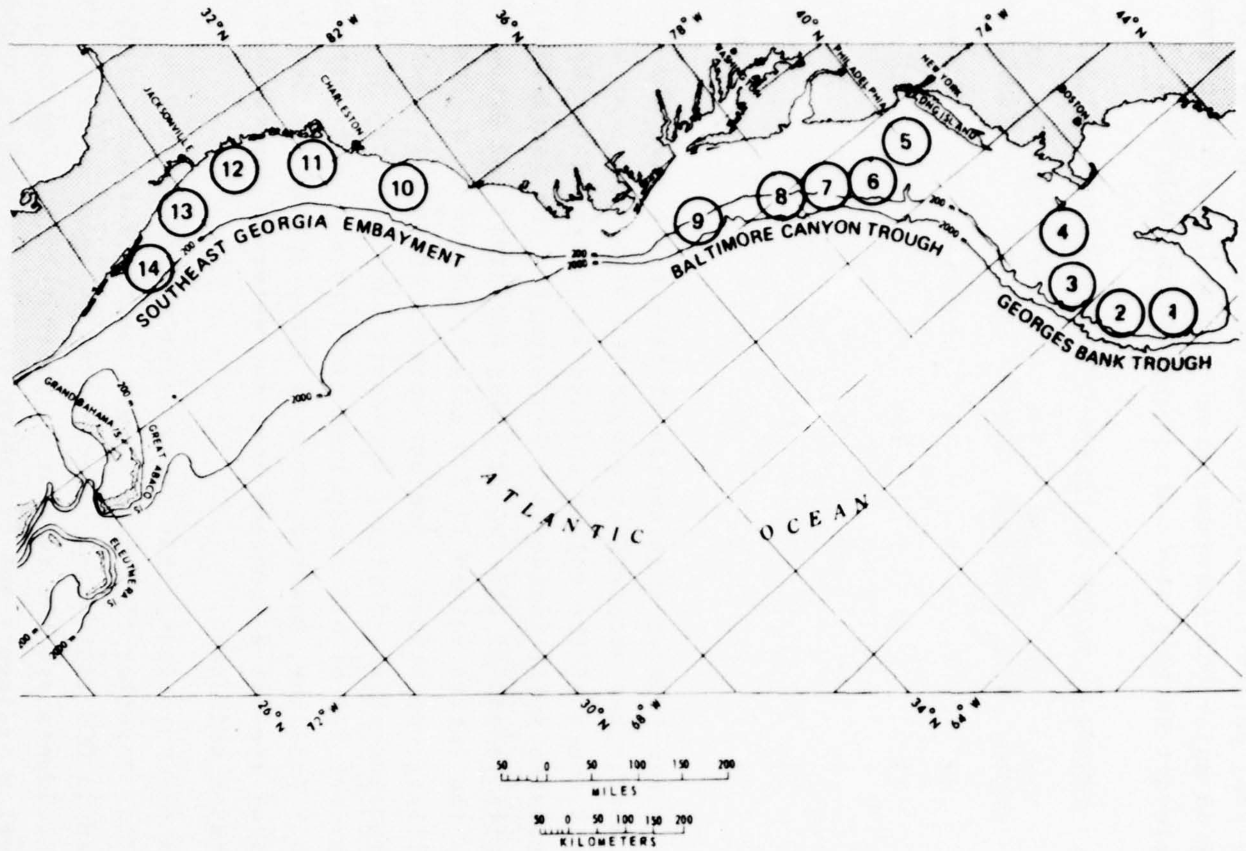
For more than 30 years the Gulf of Mexico Outer Continental Shelf (OCS) has been the most active off-shore area for petroleum production in the world. More than 18,000 wells have been drilled in the area,[4-9] and more than 2,000 oil and gas production platforms are currently in operation there.[4-10] Together with the much smaller area of the Pacific OCS in the Santa Barbara Channel, this region provides most of the data that is available for spill projections in the frontier areas of the Atlantic that are yet to be explored.

The United States Government is now in the process of leasing more than three-quarters of a million acres of land on the outer continental shelf of the coasts of New Jersey and Delaware for oil and gas development. Additional areas to the north and south are also under consideration. The mid-Atlantic sites are located in water up to 500 feet deep, 50 or more miles from shore, in areas often subjected to severe environmental conditions of wind and waves.

It has been estimated[4-11] that the recoverable petroleum from the New Jersey-Delaware sites, which lie in the Baltimore Canyon Trough (Figure 4-1), may amount to 2 billion barrels (300 M tons) or more over a field life of 25 years. The extraction of this oil, if indeed it is there, involves three distinct types of activity:

1. Exploratory drilling to find promising fields and mark their extent.
2. Well drilling in discovered fields so that the oil may be brought to the surface.
3. The operation of production platforms to collect the oil and process it for transfer (by pipeline or tank vessel) to shore.

All of these activities incur some risk of spilling oil, and provision must be made to deal with them should they occur.



Source: OCS Oil and Gas, A Report to the President, Vol. I, p. 22, April, 1974.

FIGURE 4-1. PROPOSED ATLANTIC DRILLING SITES

Oil spills on the OCS have been discussed in detail in Reference 4-12. Most of the data is from the Gulf of Mexico, covering the 20 year period from 1953 through 1972. During this time a total of 43 major OCS accidents were recorded, for which some factors relevant to this study are presented in Table 4-7.

TABLE 4-7. NUMBER OF MAJOR ACCIDENTS ON THE U.S. OCS, 1953-1972

ACCIDENT TYPE	TOTAL NUMBER	OIL WELL	OIL AND GAS WELL	OIL SPILLS	VOLUME SPILLED	FIRES	MAX DURATION
Drilling	19	0	2	2	>1 M gal	7	5.5 mos
Production	15	3	7	10	>3	12	4.5 mos
Pipeline	4	4	0	4	~7	0	13 days
Collision	2	1	0	1	0.1	1	1 day
Weather	3	3	0	3	0.4	0	3 days

It is clear from an examination of this table that the largest number of spills has occurred at production platforms. As with tank vessels, most of the volume spilled is accounted for by one or a few massive spill incidents. For example, the Santa Barbara Channel spill is one of the two drilling accidents and accounted for nearly the entire volume (1-2 M gals.) spilled as a consequence of OCS drilling operations. Another noteworthy fact is that only a small fraction of the drilling accidents have resulted in oil spills, whereas 2/3 of all production platform accidents have done so. As with drilling, however, most of these spills are small, and almost all of the oil discharged into the water is due to only two or three major accidents.

It is not surprising that every major pipeline accident has spilled oil. Together they have also accounted for most of the oil spilled in OCS accidents. It can also be said, however, that pipeline accidents are the easiest to prevent by burying the pipeline in bottom sediments and by taking care where tankers anchor off-shore. Finally, accidents caused by collisions and by weather are negligible both in numbers and in quantities of oil spilled.

Examination of Table 4-7 and additional data to 1975 thus lead to the following general observations:

1. It is very unlikely that a massive oil spill will be caused by a drilling accident. In the Gulf of Mexico, from 1965-1975 only two large spills resulted from drilling incidents, and both were in the 50,000 gal. range. All remaining spills from this cause discharged less than 2,000 gals. of oil into the water. During the same period drilling activity was at the rate of 500-1,000 wells per year.

2. Collisions of ships with either drilling rigs or production platforms, and weather induced major accidents are rare and historically have not resulted in massive spills.

3. Production platform and pipeline accidents are the sources of most spills and have resulted in the largest volumes of oil spilled. They will be discussed in more detail below.

4.2.5 Historic Platform/Pipeline Spills

The purpose here is to review historic spills from offshore platforms and associated underwater pipelines in order to ascertain their potential for future massive spills. As was done for massive tanker spills, a massive spill is taken to be one over 3,000 tons (1,000,000 gallons, or 25,000 BBL). No restriction is placed on time or location of occurrence.

The U.S. Geological Survey collects data on all U.S. OCS spills (References 4-13, 4-14). No spills over 1,000,000 gallons are recorded for the years 1971-1975. Reference 4-13 lists four platform spills and four pipeline spills worldwide from 1967 through 1972. They are not claimed to be a complete list for the period. Three of nine platform spills and three of the nine pipeline spills listed in Reference 4-15 vere over 1,000,000 gallons. These six, plus one other, are listed in Table 4-8. Investigation of the platform spills yielded enough information to estimate the outflow rates shown in Table 4-9. It should be noticed that the Main Pass Field (Platform Charlie) incident and the Bay Marchand

TABLE 4-8. SOME OFFSHORE PLATFORM AND PIPELINE SPILLS OVER 1 MILLION GALLONS, WORLDWIDE, 1967-1978

DATE	LOCATION	TYPE	MILLIONS OF GALS	REFS
Underwater Pipelines				
Oct. 67	West Delta, LA	Anchor Dragging	6.6	(1)
April 70	Persian Gulf	Break	4.0	(1)
Oct. 70	Coastal Channel	Propeller Strike	1.05	(1)
Offshore Platforms				
Jan. 69	Union "A", 10 km S.E. of Santa Barbara, CA	Blowout	3.25	(1)(2)
Dec. 70	Bay Marchand, LA Shell ST 26 "B"	Fire	2.26	(2)
March 70	Block 41C, Main Pass Field, LA, 11 miles east of Mississippi Delta	Fire	2.73	(3)
April 77	Ekofiske Field, North Sea 160 mi. from Norwegian Coast	Blowout	7.8-12.0	(4)

Notes

(1) Council on Environmental Quality, Report on OCS Oil and Gas - An Environmental Assessment, Washington DC, U.S. Government Printing Office, April 1974.

(2) Marine Pollution Bulletin, Vol. 4, No. 2, (Feb. 1973), pp. 23-25.

(3) McAuliffe, C.D., et. al., "Chevron Main Pass Block 41 Oil Spill: Chemical and Biological Investigations," 1975 Conference on Prevention and Control of Oil Pollution, San Francisco CA. Published by American Petroleum Institute.

(4) N.Y. Times, April 24-28, 1977, May 1-5, 1977.

TABLE 4-9. ESTIMATED OUTFLOW RATES FOR SOME PLATFORM SPILLS OVER 1 MILLION GALLONS, WORLDWIDE, 1967-1978

SPILL LOCATION (Date	DURATION (DAYS)	QUANTITY (GALS.)	AVERAGE OUTFLOW RATE GAL/DAY	TONS/HR
Santa Barbara, CA (January 1969)	10	3.25×10^6	325,000	45.1
Bay Marchand, LA (December 1970)	56	2.26*	90,360	5.6
Main Pass Field, LA (March 1970)	21*	2.73*	130,000	18.1
Ekofiske Field, N. Sea (April 1977)	12	7.8 - 12.	650,000 -1,000,000	90 -140

*Adjusted for fire

incident were accompanied by fires, which burned off a large part of the outflow. The rates shown for these two incidents, however, have been adjusted for the amount burned off, by means of the information in Notes (2) and (3) of the Table. In the case of the Bay Marchand incident the fire burned for the full 56 days and the quantity shown is that oil which reached the water despite the fire. Hence the outflow rate is lower than would have occurred without the fire. In the case of the Main Pass Field, the duration and quantity shown in the Table refer to the outflow after the fire was extinguished; the rate of discharge of the well during the fire was probably higher, so that the average outflow rate, had not the fire occurred, would be greater than the 18.1 tons per hour shown.

No outflow rates could be calculated for pipeline ruptures.

The conclusion to be drawn from the two Tables, therefore, is that OCS platform blowouts, in the absence of fires, can reach 100 to 200 tons per hour outflow levels.

4.3 MASSIVE SPILL LOCATIONS

The purpose of the massive spill scenarios is to provide test cases for the equipment siting configurations to be developed in later sections. The scenarios are to provide descriptions of the massive spills most likely to occur in the 1980-1990 decade. While the probability of any massive spill may be small (no attempt is made here to estimate that type of probability) the likelihood of one massive spill location, relative to others, is a more substantial number. An attempt must be made, therefore, to select those spill locations in U.S. coastal waters, that have a high probability of being the site of a massive spill, if one occurred.

4.3.1 Tanker Spill Locations

The method employed to locate potential massive spill areas is to project U.S. coastal tanker traffic to 1985. Several coastal areas were selected, covering the major parts of the U.S. coast, and the fraction of traffic through each area in 1985 was estimated. Specifically the procedure was to take U.S. crude and product import patterns for 1985 as projected in Reference 4-15 and 4-16, and to adjust the flows for Canadian traffic and for the flow of Alaskan oil as of 1985. The details of the estimates are given in Appendix D. The results are shown in Table 4-10.

Table 4-10 gives the percent of all crude and percent of all products that pass in tankers from the indicated origins to the indicated destinations, through the locations shown. For example, it can be seen that tanker traffic from Ecuador to the east coast, passing through the Mona Passage between Puerto Rico and Dominican Republic, is projected to comprise less then 0.1% of all U.S. coastal crude movements is 1985 and less than 0.1% of all product movements.

It should be noted that much of the Caribbean traffic actually originates in the Persian Gulf but is shown under Caribbean because in the original data (Reference 4-16) it was transshipped in the Caribbean. It is entirely possible that in 1985 this traffic will go directly to LOOP, SEADOCK or an Atlantic Coast DWP. If an adjustment is made for that shift, then the numbers shown in

TABLE 4-10. PERCENTAGE DISTRIBUTION OF CRUDE/PRODUCT FLOWS IN U.S. COASTAL WATERS, 1985

From \ To	East Coast	Gulf Coast	West Coast	Canada (Atlantic)
Ecuador	Mona Pass 0.0/0.0	Yucatan Ch to Gulf Coast 0.0/0.0	Pacific Coast 1.3/0.0	
Caribbean	PR-VI 6.4/38.0 (3.9)	PR-VI and Str. of Florida 8.5/3.0 (6.0)	Pacific Coast 0.7/1.1	East Coast 2.3/4.1
N. Europe	N. Atlantic 0.1/2.2	Str. of Florida 0.1/0.1	0.0/0.0	
Mediteranean	Atlantic Ocean 6.5/4.9	Str. of Florida 2.8/0.2	Pacific Coast 0.1/0.1	
SW Pacific			Pacific Ocean 6.6/0.4	
Persian Gulf	Atlantic Ocean 3.7/0.1 (6.2)	Str. of Florida 8.6/0.3 (11.1)	Pacific Ocean 7.1/0.2	
W. Africa	Atlantic Ocean 11.5/0.4	Str. of Florida 5.8/0.0	Pacific Ocean 0.0/0.0	
Canada	E. Coast 0.1/1.5	E. Coast and Str. of Florida 0.0/0.0		
Alaska	2.5/0.0	2.5/0.0	Pacific Coast 20.2/0.0	
Gulf Coast	Str. of Florida 2.2/27.3			Str. of Florida East Coast 0.0/0.1
West Coast	Windward Pass. to Gulf Coast 0.0/9.1	Yucatan Channel to Gulf Coast 0.0/3.6		

parenthesis are obtained for crude movement in the affected areas.

From Table 4-10 one observes the following high traffic areas:

	% of all Crude	% of all Product
Down the West Coast from Alaska:	25.2	0.0
Through the Straits of Florida:	28.0	36.8
Through P.R.-V.I. area and Caribbean:	14.9	41.0

The installation of DWP's on the East Coast would alter the above pattern very little, dropping the percentages of crude that pass through the PR-VI area by about 5%. It would not materially affect movement through the Straits of Florida. Similarly, the installation of DWP's on the West Coast would not alter the above numbers either.

When viewed from the points of receipt or shipment on the three coasts, Table 4-10 shows that:

1. East Coast Receipts of Crude are mainly:

   6.4% from P.R. and V.I.

   6.5% from the Mediterreanean

   3.7% from around the Cape of Good Hope

   11.5% from West Africa

   2.2% from the U.S. Gulf Coast

   30.3% of total U.S. Crude movement, almost all of which is from the south east.

2. Gulf Coast Receipts of Crude are mainly:

   8.5% from P.R. and V.I.

   2.8% from Mediterreanean

   8.6% from Persian Gulf

   5.8% from West Africa

   25.7% of total U.S. Crude movement, virtually all of which passes through the Straits of Florida.

3. Pacific Coast Receipts of Crude are mainly:

   25.5% from Alaska (North)

   15.8% from South and Southwest

4. Most petroleum <u>product</u> movement is of 3 types:

   38% up the East Coast from the Caribbean

   27% through the Straits of Florida up the East Coast

   13% out of refineries on the West Coast.

The conclusions to be drawn from the above projections, if they are correct, are that there are two coastal areas where crude oil traffic will substantially increase, and, in fact, dominate U.S. coastal crude oil movements. These are

- The Straits of Florida
- West coast from Alaska

Secondarily, heavy crude and product traffic will move up the East Coast from the Caribbean, from the Straits of Florida, and from West African ports, in addition to possible large crude carriers from the Persian Gulf to Deepwater ports in the northeast U.S. via the South Atlantic.

4.3.2 Outer Continental Shelf Spill Locations

During the 1980-1990 time period a massive spill could occur in any one of three OCS regions: the Gulf of Mexico, off the coast of Southern California, or over the U.S. Atlantic OCS. Since the last of these has as yet experienced only a limited amount of exploratory drilling, it is not possible to predict with any certainty the risks which may be associated with platform production in this "frontier" area. In the Gulf of Mexico and in the Santa Barbara Channel these risks have already been prepared for and perhaps discounted to a certain extent. On the Atlantic coast, however, they pose an unaccustomed threat. That threat seems most immediate to the mid-Atlantic region, where exploration is already underway.

Along the Atlantic Coast, the most sensitive areas appear to be the Georges Bank Trough, north of Cape Cod to the Gulf of Maine, and the Baltimore Canyon Trough south of New York, which are also the areas designated for early exploration. Of these two, the Baltimore Canyon Trough is currently being drilled and will be the first to come into production after 1980 should oil be found there.

For the most part the leased sites in this area are inside the 500 foot depth contour, whose closest approach to shore is approximately 50 miles east of Atlantic City, New Jersey. Since spills beyond 50 miles would be outside our study area, and since oil spilled beyond 50 miles from shore is more likely to drift further out to sea rather than toward shore, and since this area is probably most in need of additional response equipment, the New Jersey coast has been selected for an OCS massive spill scenario for the purposes of this study. To summarize, the middle portion of the North Atlantic provides the following "advantages" from the point of view of a worst case spill scenario:

1. Atlantic City is a highly visible tourist resort.

2. During the summer, ocean currents and surface winds have an on-shore component which could present a threat to beach areas.

3. The weather in summer is moderate with long periods of calm seas. In these circumstances the opportunity for effective response operations is maximized.

Thus, our selection of a mid-Atlantic site for a massive OCS spill is based on the following hypothetical circumstances:

- o A massive OCS spill is more likely to occur in a frontier area where experience with oil production is limited.
- o Such a spill, if it occurs, is most likely to be caused by a production platform accident.
- o The first production platforms within 50 miles of shore will probably be located off the coast of New Jersey.

- o A massive spill in this area will attract nationwide attention.
- o The mid-Atlantic in mid-summer would probably present the most favorable opportunity for an effective OCS spill response operation and would thus present a maximum challenge to the Coast Guard oil spill response system.

4.4 MASSIVE SPILL SCENARIOS

4.4.1 Tanker Spill Scenarios

The previous sections have brought out the following:

1. Massive tanker spills have historically occurred more frequently outside harbor areas than in them.
2. Massive tanker spills have been predominantly strandings (43%) and groundings (24%) and collisions (19%), based on historic spills over 3,000 tons within 50 n.mi. of a coast.
3. Massive spills have been predominantly crude and heavy oils.
4. For strandings and groundings, outflow rates in the 200-600 tons per hour range have occurred.
5. Offshore well blowouts have produced spills of up to 40,000 tons and rates of about 100-200 tons per hour (compared to 200,000 tons and 600 tons per hour for the largest tanker spills).
6. The areas most likely to see heavy tanker traffic in the 1980's are the Straits of Florida, the Pacific Northwest, and the southeast approaches to the East Coast (Cape Hatteras).
7. Explosion and/or fire are not uncommon accompaniments to groundings and collisions, and well blowouts, but not as common in the case of strandings.

8. Structural failures have been common among tankers of age 10-20 years. They have resulted in spills at sea (>50 n.mi.) about 80% of the time and in coastal areas (not harbors) the remaining 20% of the time.

At least two massive spill scenarios may be envisioned, in general terms, that embody these results:

- A tanker stranding in the Pacific Northwest Coast
- A tanker collision in the Straits of Florida

Several other scenarios, of nearly equal plausibility, easily may be envisioned.

- A tanker grounding off Puerto Rico's West coast
- A well blowout offshore of New Jersey (Baltimore Canyon)
- A tanker stranding on Georges Bank enroute St. John's New Brunswick
- A tanker stranding at the entrance to Delaware Bay, New York Harbor, Portland, Oregon, or similar confined passage
- Tanker breakup off Cape Hatteras

For the sake of concreteness, a series of events will be postulated for the first two tanker incidents, to be employed subsequently as hypothetical test cases for the equipment deployment schemes to be investigated later.

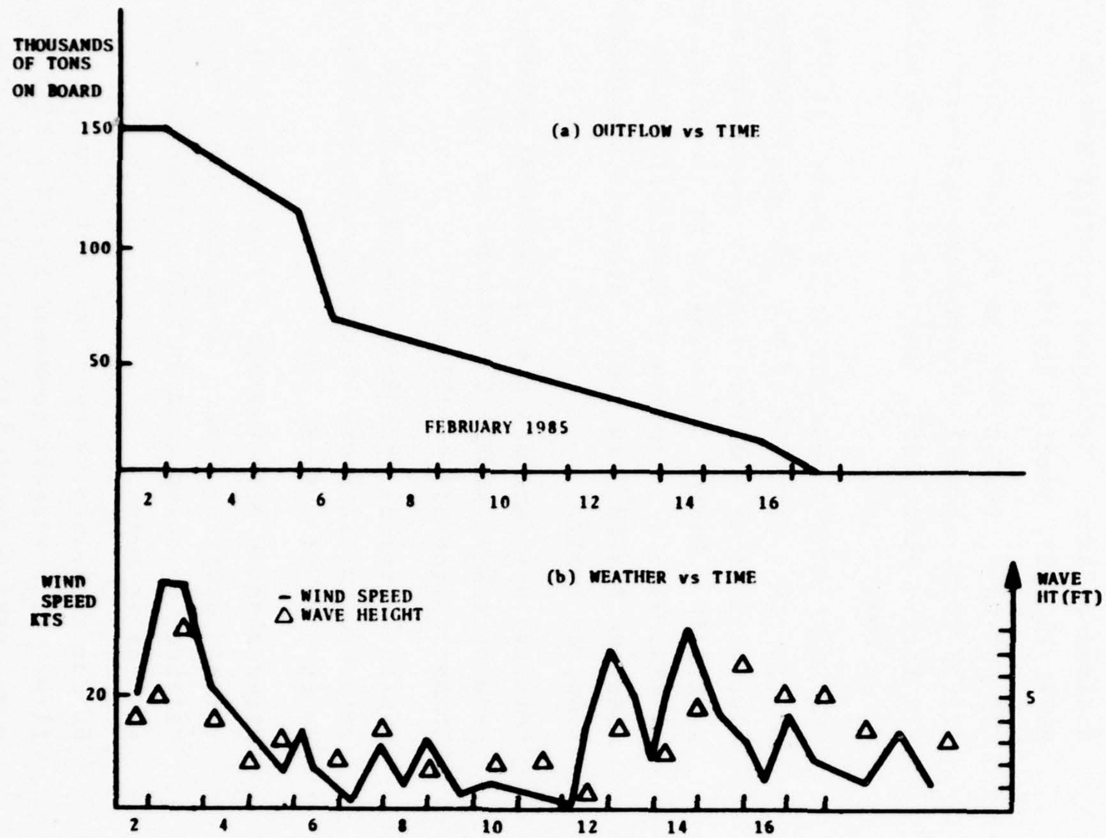
SCENARIO A, FEBRUARY 1985

Size:	165,000 DWT,
Type:	Single hull, segregated ballast, no double bottom;
Equipment:	LORAN C, inert gas, collision avoidance
Built:	1979, one of six designed for TAP service
Cargo:	154,000 tons Prudhoe Bay crude,
Destination:	Anacortes Refinery

Date, Time:	Event/Data
Feb. 2, 1800	PACIFIC PIGEON at 48 28N, 124 56W approaching staging area for entrance to Straits of Juan de Fuca the next day, experiences pump failure, due to fracture in circulating pump. Engine stops, vessel drifting SE. Winds 20 knots, gusting to 40, from the NW; current 1.9 knots at 290T, waves 4 ft, swell 4 ft.
1805	Master alerts VTS. Vessel speed 5 knots in SEasterly direction. Vessel position about 10 miles west of entrance, just south of Swiftsure Bank.
1810	Tug Heroic receives notification, presently 5 miles east of entrance to Straits of Juan de Fuca, immediately proceeds to assist at 10 knots. Estimated time of arrival 1940.
1840	PACIFIC PIGEON at 48 27N 124 55W, drifting SE at about 7 knots, wind 30 knots, swell from N west at 5-10 ft, waves 5 ft.
1940	Vessel at 48 25N, 124 51W, tug Heroic arrives.
2010	Heroic secures line to vessel;
2030	Line parts; PACIFIC PIGEON continued drift to SEast. coordinates 48 25N, 124 50W. Winds increase to 40 knots, seas to 6 ft.
2200	Heroic re-secure line.
2300	Line parts a second time.
Feb. 3, 0100	PACIFIC PIGEON continues to drift toward SEast. Presently about 2 miles from Duntze Rock. 2nd tug arrives, but neither is able to approach PACIFIC PIGEON because of heavy seas. Crew removed by helicopter.

Feb. 3, 0210	PACIFIC PIGEON aground on Duntz Rock, Cape Flattery, in heavy swell. Visibility 1 mile. Light rain. Master still on board.
0800	Oil slick about one-half mile long forms about PACIFIC PIGEON, now firmly stranded on Duntze Rock. No. 6 port and center tanks and No. 5 port tank breached. Engine room and pump room flooded. Tug Heroic attempting to free vessel, which is about 1-1/2 miles from shore. Master leaves vessel via helicopter.
1200	Slick five miles long, 1 mile wide extending SE From Cape Flattery along coast. Seas 8 ft, swells 8 ft, wind 40 knots, gusting to 60.
Feb. 4, 0600	Winds drop to 10 knots from NWest, waves to 4 ft. Favorable weather expected for next 48 hours. Slick 10 miles long, 1 mile wide along coast.
Feb. 5, 0800	PACIFIC PIGEON pivots on center section, begins to leak more rapidly.
Feb. 6, 1000	Vessel breaks in two; slick reaches Cape Alava. Smaller slick in Straits of Juan de Fuca.
Feb. 10,0800	Bow section almost free; stern begins to rotate to South.
Feb. 17,1000	Both bow and stern sections submerged. Depth charges used to sink both halves to prevent them from floating off and becoming hazards to navigation.

Figure 4-2 gives the assumed discharge profile (a) and shows wind speed and wave height (b) Water temperature is 50 degrees Farenheit throughout.



DATE, FEBRUARY 1985

FIGURE 4-2. OUTFLOW AND WEATHER CHART FOR PACIFIC PIGEON SCENARIO A

SCENARIO B, JULY 1, 1985

Vessel #1: UNIVERSAL WONDER, 356,000 DWT, 1145 ft long draft 85 feet. Cargo: 335,000 tons Arabian crude. On voyage from Gulf of Persia to LOOP Equipment: LORAN C, shipboard Radar, Collision Avoidance Radar. Redundant steerage system. Built in 1977, Swedish Registry.

Vessel #2: T/S BUNKER C, 15,000 DWT, 30 ft draft, Carrying 12,000 tons residual from Houston refinery to New York. Built 1965, American Flag. No LORAN C, no radar, ADF.

July 1, 0800 UNIVERSAL WONDER underway at 15 knots, 24 35N, 83 22W (25 n.miles SW of Dry Tortugas) heading 210, Visibility 7 miles, wind 10 knots from east, seas 2 ft. BUNKER C heading SE at 15 knots, at 24 41N, 83 31W. Captain of UNIVERSAL WONDER observes BUNKER C on radar, attempts communication, no reply.

0810 Relative distance 5.5 n.mi.; UNIVERSAL WONDER reduces power; BUNKER C continues on course. Communication not established.

0825 BUNKER C strikes UNIVERSAL WONDER port side amidships at 10 knots. Both vessels immediately catch fire 24 39N, 83 26W.

0830 Crews abandon both vessels. Power off; both vessels drifting free. Large quantities of oil released to ocean from UNIVERSAL WONDER, where most of it burns.

0930 Rescue vessels pick up crews, but cannot put out fire. Fire vessels summoned from Key West 85 n.mi. east scheduled to arrive 7-8 hrs.

1710 Fire on BUNKER C goes out as fire fighting vessels from Key West arrive. UNIVERSAL WONDER still burning from aft two-thirds.

July 2, 1000	Fire on UNIVERSAL WONDER extinguished. Heavy oil leakage continued from UNIVERSAL WONDER, but ceases from BUNKER C. Slick spreads in westerly direction extends from 2 miles east of vessels to 5 miles west of vessels. Both vessels continue to smoke heavily.
July 3, 0800	Both vessels taken under tow as smoke subsides. Since UNIVERSAL WONDER continues to leak heavily, it is decided to tow her to the west and sink her in the Gulf of Mexico.

Leakage and burn rates are shown in Figure 4-3 together with wave and wind profiles.

July 4, 0900	Several slicks are observed in 20 x 20 n.mi. area, ranging in size from 1/2 x 1/2 mile to 10 x 5 miles. Witnesses said BUNKER C's port bow struck the UNIVERSAL WONDER about 200 ft forward of the bridge. "UNIVERSAL WONDER had a hole about 100 feet long above the waterline, extending down into the water." Both vessels remained afloat.
1200	Winds shift to south east, drop to 5 knots. Leakage of heavy oil now detected from BUNKER C; cannot enter Key West harbor, remains 10 n.mi. outside Key West; leakage rate approximately 100 gallons/hr. UNIVERSAL WONDER 120 n.mi. west of Key West, under tow due westerly direction.
July 5, 0800	Seas rise to 5 ft, wind to 30 knots, from the south east; heavy rain, thunder and lightning. Towing of UNIVERSAL WONDER stops.
July 6	Towing operation recommences.
July 7, 1000	UNIVERSAL WONDER bombed and sunk at 24 30N, 86 00W with approximately one-half her original cargo still aboard. Leakage ceases on BUNKER C,

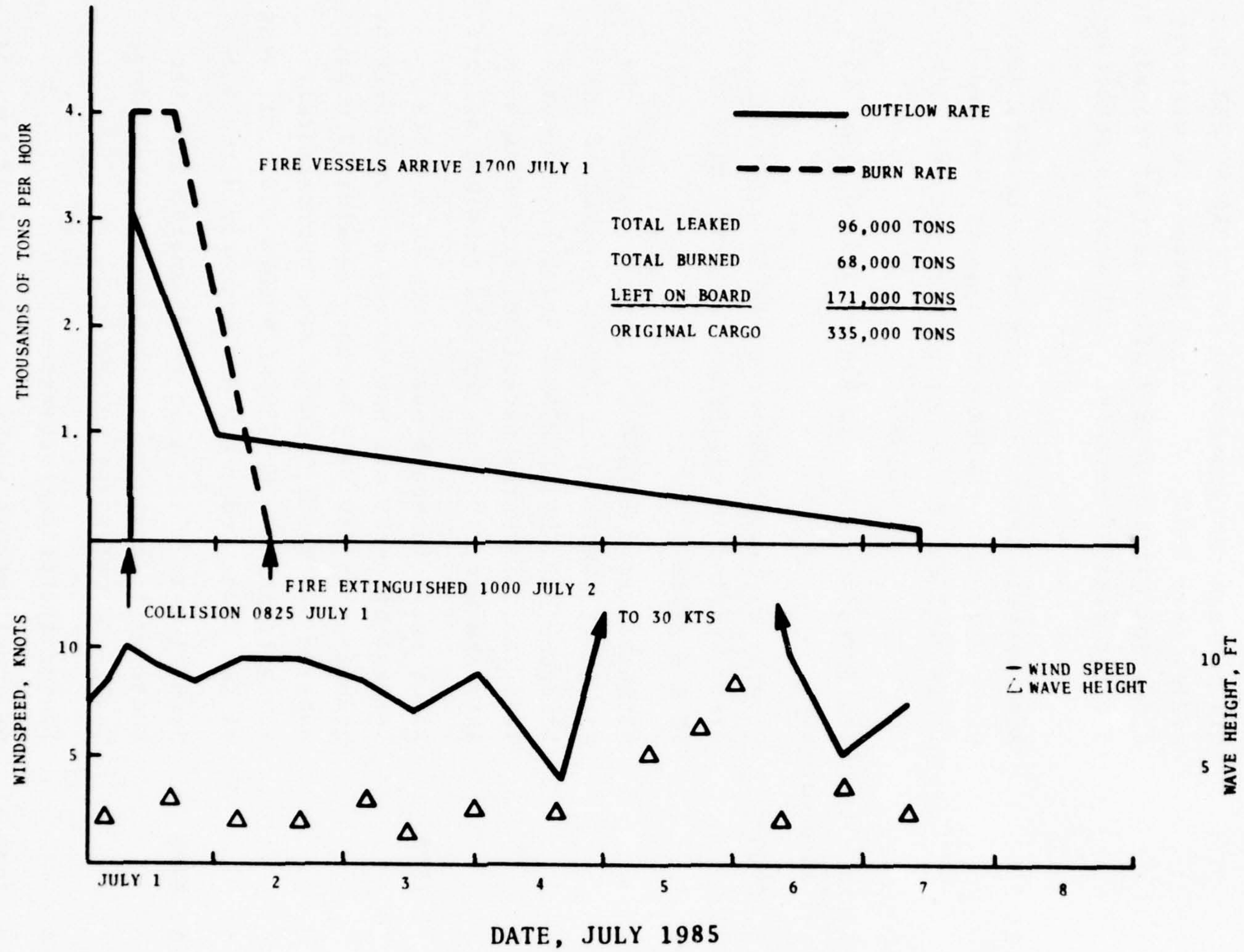


FIGURE 4-3. OIL OUTFLOW AND WEATHER FOR UNIVERSAL WONDER SCENARIO B

which is towed into Key West harbor for offloading and eventual scrapping.

Heavy oil slicks come ashore on Garden Key and Loggerhead Key, FL. Giant oil slicks to west and north.

Approximate total areas covered by slick over the seven days are as follows, (n.mi. x n.mi.):

July 1	1 slick	1/2 x 1/2
2	2 slicks	10 x 5 each
3	2 slicks	20 x 15 each
4	2 slicks	30 x 15 each
5	3 slicks	40 x 10 each
6 7	several slicks	150 square miles total

4.4.2 OCS Massive Spill Scenario

Before a detailed OCS massive spill scenario can be fully developed, two additional circumstances must be considered. They are (1) the immediate cause of the production platform blowout, and (2) whether or not the blowout is accompanied by fire.

We have already seen that neither a ship collision nor severe weather is likely to lead to a massive spill. Aside from human error, the only other possibility is an earthquake. Earthquakes of magnitude comparable to Richter 7 have been reported[4-12] in the last few centuries in the northern sector of the U.S. Atlantic coast. Only one has been reported in the southern sector. On the average such earthquakes have happened about once per century. There is therefore a 25% chance that one severe shock will occur during the 25-30 year life of a mid-Atlantic oil field. If the platform structure is designed to withstand an earthquake of magnitude 7.2 Richter with a safety factor of 1.5, then according to Reference 4-12, there is a 15% chance that it will fail if an

earthquake should occur during its expected life. The probability of failure and a well blowout is thus about 4%, small but much larger than that due to any other cause.

Structural failure in an earthquake may be brought about either by dynamic shaking or by foundation failure due to loss of soil stability and ground slumping. The result of such failure would be that some if not all well-pipes would be broken. Manual valving systems on the platform could not be operated, and the prevention of leaks would depend on the automatic operation of all subsurface valves, some of which would undoubtedly fail. Plugging the leaking wells would require first, that they be identified and second, that relief wells be drilled from a floating rig through which water, mud and cement could be pumped. Operations of this magnitude take one or more months during which the spill goes on unabated.

It is not unlikely that during the course of such an event, a fire will be ignited and that the oil will begin to burn. In a sense this relieves the surface clean-up requirements since most of the surface oil will be burned off, and it will become dangerous, if not impossible to approach the spill region in a boat or other vessel. Therefore, in order to permit the response organization to be as effective as possible, it will be assumed that little gas accompanies the leaking oil and that no fire breaks out. The adequacy of the response operation 50 miles from shore will thus be highly visible.

With these assumptions, the following events are supposed to take place at production platform "A" 50 miles east of the New Jersey coast (39°30'N, 73°W) in 200 feet of water.

OCS Massive Spill Scenario, July 1987. Scenario C.

Date	Event/Data
July 4, 1987	After 60 years of quiescence, at the beginning of the summer vacation season, an earthquake of magnitude 7.5 Richter occurred with epicenter at 38°N

latitude near production platform "A" in the Central Baltimore Canyon Trough, 50 miles east of Atlantic City, New Jersey. Local slumping of the underlying soil caused the foundation of the platform to fail, and the platform slowly collapsed, shearing all of the 12 well pipes feeding the platform.

July 5	All surviving platform personnel have been rescued by helicopter. It has been learned that there was no opportunity to operate the manual safety valves. Since two separated oil slicks have been reported by helicopter pilots, it is assumed that 2 of the 12 subsurface automatic safety valves failed to operate properly and that two well-pipes are leaking oil.
July 6	Estimates from nearby ships and overflying aircraft indicate that oil is leaking to the surface at the rate of 50 bbls/hour from each of the two wells, which have now been identified as wells No. 4 and No. 7. Their combined spill rate is about 100,000 gals per day.
July 7	The weather continues fair. Seas are favorable with wave heights less than 2 feet. The water temperature is 68°F, and the surface current speed is 2 knots toward the northwest. The oil slick is spreading and drifting shoreward. A semi-submersible drilling rig is under tow to the spill site to begin drilling a relief well.

July 8	Wind freshening and wave heights increasing.
July 9	Significant wave height greater than 6 feet. Expected to persist for at least another day. Oil continues to spread and meander northwestward toward shore.
July 17	Relief well drilling operations have begun with rig No. 1. It is estimated that 1.5 M gals of oil have been spilled to date. During the past week wave heights have remained under 5 feet and have moderated to 3 feet over the past two days.
July 25	Drilling rig No. 2 is on-site and has begun drilling operations.
July 30	Weathered tar balls are beginning to wash ashore on New Jersey beaches near Atlantic City. Strong winds and seas greater than 9 feet predicted for tomorrow and likely to persist for 12-24 hours.
Aug. 3	The first pump-in operation was begun at 8:15 A.M. Sea water was pumped into the No. 4 relief well by a pump barge at the rate of 70 bbls/minute. Six hours later the flow of oil from Well No. 4 was observed to diminsh markedly. Water injection continued throughout the night. Seas have subsided to 3 feet.
Aug. 4	Since there was no longer evidence of oil over the site of Well No. 4, it was decided to inject mud and cement to serve as a subsurface plug. Injection operations were completed on Well

	No. 4 by noon. Well No. 7 continued to leak, but at a reduced rate.
Aug. 7	The second relief well has been completed and it is expected that No. 7 well will be plugged by tomorrow.
Aug. 8	Both wells plugged. No further oil leakage is observable. Estimated volume of oil spilled, 3.5 million gallons. Remaining oil slick broken into large patches scattered over many square miles of ocean. Tar balls continue to come ashore in New Jersey and southern Long Island.

Oil outflow rates and weather profiles for Scenario C are shown in Figure 4-4.

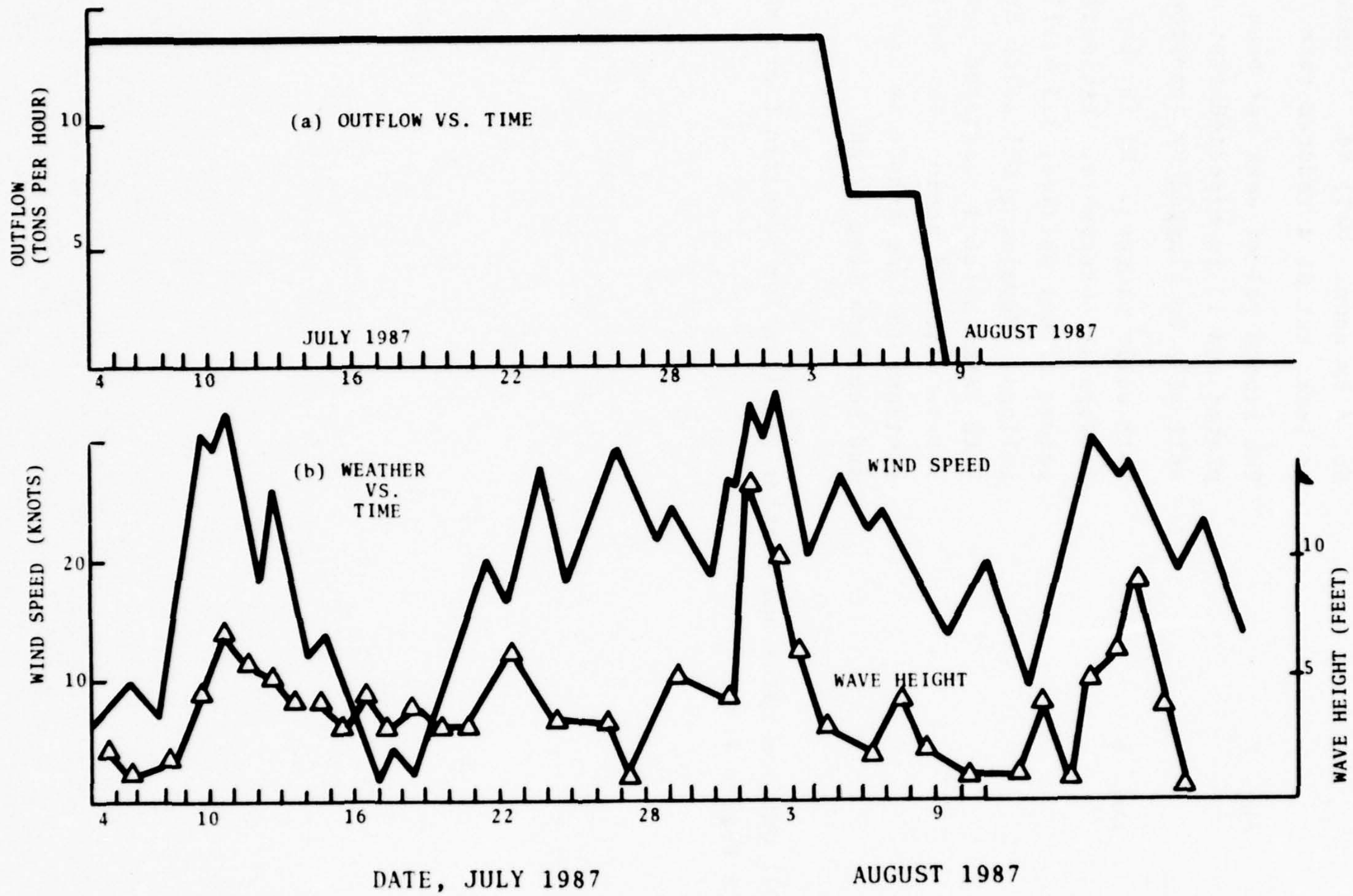


FIGURE 4-4. OIL OUTFLOWS RATES AND WEATHER PROFILES FOR PLATFORM SPILL SCENARIO C.

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5. ENVIRONMENTAL CONDITIONS

5.1 THE OCEAN ENVIRONMENT AND ITS RELATION TO SPILL RESPONSE

Numerous factors contribute to the effectiveness of efforts to respond to major oil spills in coastal waters. Some of these are subject to a measure of control, such as advance planning, the availability of equipment and trained personnel, and prompt logistical support; other circumstances cannot be controlled since they depend on the location of the spill, the season of the year, and the local weather. These environmental factors can only be anticipated in a probabilistic way. Two sets of circumstances do provide bounds on the planning possibilities, however. These are the favorable conditions of mid-summer and the adverse ocean environment of mid-winter. Within the present state-of-the-art only limited response possibilities are available during worst case situations. Present day equipment is most effective in more moderate circumstances. Thus, one planning approach is to provide the resources needed when all the available equipment can be used to advantage and then to estimate how these resources may fall short in worst-case situations and how the short-fall may be compensated. It is the purpose of this chapter to define where and when these contrasting conditions are likely to exist.

In coastal waters the casualty most likely to befall a large tanker is a stranding or grounding. Although a grounding (transient contact with the bottom) may result in a ruptured tank, the integrity of the vessel itself is often not impaired so that, except in severe weather, it can proceed either under its own power or under tow to a safe anchorage where it can be unloaded by lightering. A stranding, on the other hand, immobilizes a leaking tanker on rocks or shoals, subjects the ship to severe structural stresses due to tides, waves, and currents and requires that the vessel be refloated as rapidly as possible if the situation is to be saved.

The ability to off-load intact tanks and to recover spilled oil in open water diminishes rapidly in deteriorating weather. The environmental factors that contribute most directly to the success or failure of these operations are the wind, waves, and temperature at the surface of the water. Strong local winds and accompanying waves make lightering dangerous, if not impossible. Furthermore, booms and skimmers for containing and collecting spilled oil are effective only in moderate sea-states, and the efficient transfer of recovered oil to storage vessels or bags requires a sufficiently high sea surface temperature that the viscosity of the spilled oil is less than the maximum pumping viscosity.

Of secondary importance to pollution response operations in open water are the surface current and the general atmospheric weather. Except for Cape Hatteras and some areas of the Pacific Coast, 98% of all observed surface currents are less than 3 knots, which is somewhat above the upper limit of effective operation for containment booms. But even in the most adverse circumstances, the technique employed would be to secure the ends of the boom to boats and maneuver to reduce the relative speed in the water to a workable value.

As for the general weather at sea, only the wind exerts a direct effect and has been reliably recorded. Other variables, such as precipitation and visibility, may hamper one or another aspect of a response operation for a short time, but are not likely to bring it to a halt in the way that a heavy sea would. Furthermore, reliable data on these meteorological variables at sea are difficult to obtain and often subject to large errors. For these reasons weather statistics, as such, are not included in the tables at the end of this chapter.

5.2 ENVIRONMENTAL FACTORS

The environmental factors which determine most directly the fate of oil spilled on the ocean and influence the probable effectiveness of response actions are:

1. Surface winds
2. Sea-waves and swell
3. Surface water temperature
4. Surface water current.

All of these factors vary with the seasons of the year and are least favorable in the higher latitudes in winter, where the hours of available daylight may also severely limit the response operations.

The ultimate source of most compilations of ocean data is the marine data tape file, Tape Data Family-11 (TDF-11), maintained at the National Climatic Center. TDF-11 contains more than 31 million surface marine observations from transient ships, fixed ocean weather stations, buoys, and other sources. The observations come from all parts of the world's oceans and extend in time over more than a century. They have varying degrees of reliability and are known to be subject to a number of biases. For example, most modern observations were made along shipping lanes, with little or no data available from other areas. Also, recent data, especially in higher latitudes, is subject to a "fair weather bias" since ships are frequently diverted from areas of bad weather. For this reason environmental conditions in the more northerly regions, where bad weather is a more frequent occurrence, may be somewhat worse than is shown by the data.

5.2.1 Surface Winds

Winds at sea affect response operations both directly and indirectly. Local winds induce surface waves, and the wind speed is directly related to the sea state (wave height). More distant winds result in ocean swell waves, usually of relatively small amplitude but long wavelength. In addition to these indirect effects, the wind influences the movement of spilled oil imparting to it a velocity component equal to approximately 3% of the wind speed in the direction of the wind vector. In a 20 knot wind this component may be as much as 0.5 knot. High winds also impede

lightering near a stranded vessel and make helicopter operations more difficult and hazardous. For the purposes of this study, wind speeds less than 20 knots were not considered to be a serious impediment to response operations.

5.2.2 Sea-State and Swell

The state of the sea refers to waves on the ocean surface that are generated by local winds blowing over the water. The waves are of short period and of various heights, giving the impression of a dynamic, irregular surface. The wave propagation direction is roughly the same as the wind direction.

Short-period waves affect recovery operations in the first instance by setting limits on the beneficial use of containment and skimming devices and secondly by adversely affecting the ability of vessels and crews to perform difficult and often dangerous tasks. As a general rule, containment booms and skimmers designed for use in open water lose most of their effectiveness in sea-state 3 or greater (wave heights > 5 ft.), and some boats begin to experience difficulty in waves 8-10 ft. high. The 5 ft. height is the divide chosen for the tabulation at the end of this section.

Sea swell is due to more remote winds and consists of long period waves that may produce excessive stress on large, flexible objects such as booms and storage bags that float on the surface of the water. However, swell is usually not a direct impediment to response operations since it is less than 6 ft. high most of the time in all seasons. Some general features of sea-swell along the U.S. coasts are given in Table 5-1 to support this conclusion.

Along the Pacific Coast sea-swell appears to be a more significant factor, but data are much less detailed than for the Atlantic Coast. However, there is a significant on-shore component at all times, especially in the northern portion.

TABLE 5-1. SEA-SWELL CHARACTERISTICS

U.S. ATLANTIC COAST

Month	Percentiles < 6 FT	Percentiles > 12 FT	Direction
Feb.	50.0	5.0	Off-shore
Aug.	80.0	2.0	Parallel to coast

U.S. PACIFIC COAST

Month	Percentiles < 6 FT	Percentiles 7-12 FT	Percentiles > 12 FT	Direction
Feb.	15.0	20.0	65.0	On-shore
Aug.	75.0	15.0	10.0	Parallel to onshore

5.2.3 Surface Water Temperature

The water temperature at the surface of the sea exerts a variety of influences on both spilled oil and on subsequent response operations. In a warm, sunlit ocean most of the lighter fractions of crude oils spilled on the water will evaporate in a short time, leaving behind a viscous residue to be recovered. On the other hand, if the surface water is cold, evaporation is slower, and the viscosity of the residue increases exponentially with decreasing temperature, quickly reducing the efficiency with which the skimming and transfer of recovered oil to storage containers can be accomplished.

In order to off-load crude oil from a stricken tanker, the oil in the tanks must be maintained at a pumpable viscosity, which requires heat to be supplied either by the ship itself or by an external source. Lacking such heat, the oil will slowly cool until its viscosity is higher than the maximum pumping viscosity (~ 1000 centistokes). No. 6 fuel oils reach this value when allowed to cool to a temperature between 80 and 100 degrees F. For some No. 5 oils this viscosity is not reached until the temperature has dropped to about 30 degrees F. At lower temperatures, pumping becomes difficult and inefficient, if not impossible.

5.2.4 Surface Currents

The principal effect of surface currents on a spill incident in open water is to cause the oil to drift away from the source of the spill and to disperse over large areas of the ocean. (This process is also influenced by the surface wind and the tendency of the oil to spread). In order to recover any significant quantity of spilled oil from the surface of the sea, it is necessary to reduce the dispersion and to concentrate the oil for efficient skimming. The mechanical means available to accomplish these objectives are the open water containment barriers (booms) that have been developed for this purpose. However, when its speed relative to the water is greater than 1.0 knots, none of these booms works very well. In faster currents, boats may be used to hold the boom and allow it to drift enough to keep the relative speed through the water below the value at which the oil encountered is entrained in the water and swept under the barrier. Whatever the tactical approach, it is fortuitous that ocean currents usually do not exceed 1 knot so that even a moored boom could conceivably contain some amount of oil.

5.3 ENVIRONMENTAL DATA TABLES

This chapter concludes with a set of tables of selected environmental conditions that characterize the coastal regions of the U.S. and should be considered in planning for oil spill response operations. The tabulated data have been compiled and derived from a number of sources - all based on TDF-11. Wherever appropriate, the data have been arranged by coastal subregion as indicated in Table 5-2. For convenience these sub-regions have been grouped into five zones, as follows:

a. Atlantic Coast (North)
   Bay of Fundy to Cape Hatteras

b. Atlantic Coast (South)
   Cape Hatteras to Cape Sable, FL

c. Gulf Coast
   Straits of Florida to the Rio Grande

d. **Pacific Coast (South)**

San Diego, CA to Pt. St. George (42°N)

e. Pacific Coast (North)

Pt. St. George to Canada.

Although the tabulated physical quantities tend to vary in a smooth and unexceptional way between coastal zones, it should be noted that there is a marked and rather steep change at Cape Hatteras, which may have implications for response planning.

5.3.1 Wind and Waves

Basic data on wind and waves are presented in Table 5-3 for the mid-winter month of February and in Table 5-4 for the mid-summer month of August. The data are interpolated percentiles derived from the tabulations of Marcus.[5-1] The first column of data shows the percent of all observations of wind speed in the data base which were less than 20 knots. At this speed the wind is termed a "fresh breeze" (Beaufort number, 5) and marks the onset of rough seas (5 foot waves with whitecaps). Column 2 shows similar percentiles for waves less than 5 feet high. These generally follow the wind data, although the percentiles are smaller, most noticeably so in winter. During February in the Atlantic the waves are 5 feet high or higher in 50% or more of all observations, and the seas are considerably rougher south of Cape Hatteras than they are to the north. A similar tendency manifests itself along the Pacific coast where the seas are noticeably rougher north of the 42nd parallel. In August, along the Atlantic and Gulf coasts, no more than 5% of the observed wind speeds exceed 20 knots, except in the most northerly sub-regions of the Atlantic, and the seas, of course, are significantly calmer. The change from winter to summer is not so great along the Pacific coast where strong winds and rough seas are often recorded in August.

5.3.2 Water Temperature

The last four columns of Table 5-3 and 5-4 present selected aspects of the surface water temperature. These selections are

TABLE 5-2. U.S. COASTAL ZONES AND SUB-REGIONS

ZONE	SUB REGION	GEOGRAPHIC EXTENT	COORD BDRS
Atlantic Coast (North)	04	Bay of Fundy to Cape Cod	45°N-42°N
	05	Cape Cod to Montauk Pt.	42°N-41°N
	06	Montauk Pt. to Barnegut Bay	41°N-40°N
	07	Barnegut Bay to Cape Charles	40°N-38°N
	08	Cape Charles to Cape Hatteras	38°N-36°N
Atlantic Coast (South)	09	Cape Hatteras to Cape Fear	36°N-34°N
	10	Cape Fear to Savannah GA	34°N-32°N
	11	Savannah GA to Daytona FL	32°N-29°N
	12	Daytona FL to Cape Sable	29°N-25°N
Gulf Coast	13	Straits of Florida	79°W-83°W
	14	Cape Sable to Punta Gorda FL	25°N-27°N
	15	Punta Gorda FL to C. San Blas	82°W-86°W
	16	Cape San Blas to Biloxi MS	86°W-89°W
	17	Biloxi MS to Vermillion Bay	89°W-92°W
	18	Vermillion Bay to Galveston TX	92°W-95°W
	19	Galveston TX to Rio Grande R.	95°W-97°W
Pacific Coast (South)	22	San Diego to Los Angeles	33°N-34°N
	24	Los Angeles to Cape S. Martin	34°N-36°N
	25	Cape S. Martin to Pt. Reyes	36°N-38°N
	26	Pt. Reyes to Pt. Delguda	38°N-40°N
	27	Pt. Delguda to Pt. St. George	40°N-42°N
Pacific Coast (North)	28	Pt. St. George to Heceta	42°N-44°N
	29	Heceta to Columbia R.	44°N-46°N
	30	Columbia R. to Str. of J. deFuca	46°N-48°N
	31	Str. of J. deFuca to Canada	48°N-49°N

Notes

(1) Coastal sub-regions extend to 100 miles or more off-shore.

(2) Sub-regions based on U.S. Navy Weather Service designations.

TABLE 5-3. FEBRUARY ENVIRONMENT

SUB REGION NUMBER	PERCENTILES				DEGREES F	
	WIND SPEED <20 KTS	WAVE HEIGHT <5 FT	WATER TEMP. <35 F	WATER TEMP. <50 F	*MEDIAN WATER TEMP	**1% ILE WATER TEMP
	ATLANTIC COAST (NORTH)					
4	57.1	50.0	25.0	99.0	38	29
5	59.4	50.0	5.0	95.6	42	31
6	75.0	62.5	15.0	96.6	40	29
7	75.0	50.0	3.0	75.0	46	33
8	75.0	58.3	1.0	50.0	51	35
	ATLANTIC COAST (SOUTH)					
9	58.3	41.8	0.3	9.7	67	40
10	58.3	41.7	0.0	0.5	72	54
11	75.0	50.0	0.0	0.0	75	64
12	78.6	62.5	0.0	0.0	75	65
	GULF COAST					
13	83.6	75.0	0.0	0.0	75	63
14	85.0	75.0	0.0	0.0	72	61
15	79.0	62.5	0.0	0.0	70	56
16	77.0	58.3	0.0	0.5	71	55
17	77.9	58.3	0.0	0.6	70	57
18	77.5	58.3	0.0	0.6	66	52
19	77.0	62.5	0.0	0.0	68	54
	PACIFIC COAST					
22	91.7	75.0	0.0	0.8	59	51
24	83.9	58.3	0.0	3.0	56	49
25	76.7	50.0	0.0	10.0	54	47
26	78.1	50.0	0.0	20.0	53	47
27	75.0	50.0	0.0	25.0	52	47
28	75.0	37.5	0.0	50.0	50	45
29	70.8	25.0	0.0	62.5	49	44
30	70.8	25.0	0.0	81.7	48	40
31	76.4	37.5	0.0	95.8	46	39

Notes:

*The MEDIAN WATER TEMP. is the 50 percentile for February.

**The monthly minimum 1% ILE WATER TEMP. occurs in February in almost every sub-region. Otherwise in March.

TABLE 5-4. AUGUST ENVIRONMENT

SUB REGION NUMBER	PERCENTILES				DEGREES F	
	WIND SPEED <20 KTS	WAVE HEIGHT <5 FT	WATER TEMP. >50 F	WATER TEMP. >65 F	MEDIAN WATER TEMP	1% ILE WATER TEMP
ATLANTIC COAST (NORTH)						
4	91.0	96.3	75.0	25.0	59	45
5	92.1	85.0	100.0	75.0	69	55
6	95.0	85.0	100.0	95.0	71	62
7	96.0	85.0	100.0	100.0	75	66
8	94.2	85.0	100.0	100.0	78	68
ATLANTIC COAST (SOUTH)						
9	94.2	75.0	100.0	100.0	82	73
10	94.2	75.0	100.0	100.0	84	77
11	95.6	85.0	100.0	100.0	85	80
12	95.8	85.0	100.0	100.0	85	79
GULF COAST						
13	96.3	95.0	100.0	100.0	86	81
14	96.5	95.0	100.0	100.0	86	81
15	96.5	95.0	100.0	100.0	85	81
16	96.1	95.0	100.0	100.0	85	80
17	96.9	95.0	100.0	100.0	86	80
18	96.3	95.0	100.0	100.0	86	80
19	96.3	95.0	100.0	100.0	85	79
PACIFIC COAST						
22	96.1	85.0	100.0	75.0	67	59
24	83.6	62.5	100.0	25.0	62	53
25	76.8	58.3	100.0	5.0	60	52
26	70.0	50.0	97.0	12.0	59	49
27	70.8	58.3	91.0	3.0	57	47
28	80.4	62.5	91.0	4.0	58	47
29	83.9	62.5	98.0	5.0	61	49
30	91.0	75.0	100.0	5.0	60	52
31	93.8	75.0	97.0	4.0	58	49

based on some general features that can be found in 5-2. For example, the minimum (5%) observed sea surface temperature for February in the coastal waters of the Atlantic is less than 32°F from the Bay of Fundy south to latitude 40°N (somewhat south of Long Island). From thereabouts, the 34°F, 5% isotherm parallels the coast, 60 nautical miles from shore, south-westerly to the entrance to Chesapeake Bay at latitude 37.5°N. Further south the 5 percentile temperature rises rapidly to 50°F at latitude 35°N, near Cape Hatteras. These geographical "break-points" suggest divisions by temperature at 35°F and at 50°F.

A further consideration has to do with the pumpability of No. 5 and No. 6 residual fuel oils, which are common cargoes in coastal waters. Type B, No. 5 residual fuel oil (a blend of distillate and vacuum still residual crude) is the heaviest oil which can still be pumped easily at 50°F (viscosity = 2000 SSU or 450 centi-stokes).[5-4] For this oil the maximum pumping viscosity of 1000 centistokes (5000 SSU) occurs at about 30°F. All No. 6 oils already reach their maximum viscosity when cooled to temperatures between 80°F and 100°F. It may also be noted that the pour point of many No. 6 oils is in the neighborhood of 50°F.

Thus, data columns 3 and 4 for February show respectively the percentiles of observations (and times) for which even Type B, No. 5 cannot be pumped and all No. 6 ceases to behave as a liquid. Note that these frequencies are insignificant south of Cape Hatteras on the east coast. Along the Pacific coast, the surface temperature never falls below 35°F, but the 50°F percentiles vary from nearly zero at the southern limit to almost 100% at the Canadian border, with a sharp break at latitude 42°N.

Finally, the last two columns list the 50 percentile (median) and 1 percentile water temperatures. The break near Cape Hatteras is again evident in the data. Summer observations on the Gulf Coast show that even No. 6 is pumpable at the surface water temperatures that are likely to be encountered there.

5.3.3 Persistence of Favorable Seas

The open water oil recovery systems developed by the Coast Guard and others are required to be reasonably efficient in waves up to 5 feet high. Therefore, in order to estimate the effectiveness of a spill response operation in recovering oil from the surface of the sea, it is necessary to know how often and for how long waves less than 5 feet high can be expected during various seasons of the year. Such information can be extracted from a series of plots to be found in Marcus, which present the frequency of occurrence of waves less than 6 feet high and the frequency of occasions during which such waves persist as a function of their duration. A typical set of plots is shown in Figure 5-1.

Table 5-5 was prepared from these curves in the following way. First, it was assumed that the bar chart showing the frequency of observation of waves of given heights corresponds to the fraction of time during the 3 month period that waves less than 6 feet high were actually present. This total time in hours (and days) is shown in column 3 of the table. For the winter months at Diamond Shoals this time amounts to 64% of 2160 hours or 1382 hours. The number of separate occasions of 10 hours or longer for which this condition existed is read from the left curve as 130% of the 26 average number of occasions that comprise the 100% baseline. Thus, there were 34 occasions during the 3 month period when the waves decreased in height to less than 6 feet from some higher value (column 5). Dividing these two numbers, 1382/34, one arrives at an average duration for all occasions of 40 hours (column 4).

The remaining numbers are the products of percentages taken from the curve multiplied by 26. For example, one would expect $.60 \times 26 \approx 15$ occasions with durations >40 hours, and $34-15 = 19$ occasions with durations <40 hours (columns 6 and 7). Similarly, on an average of $.42 \times 26 \approx 10$ occasions during the 3 month period, the wave height fell below 6 feet and remained below this level for more than 50 hours. This number amounted to 10/34 or 29% of all the observed occasions.

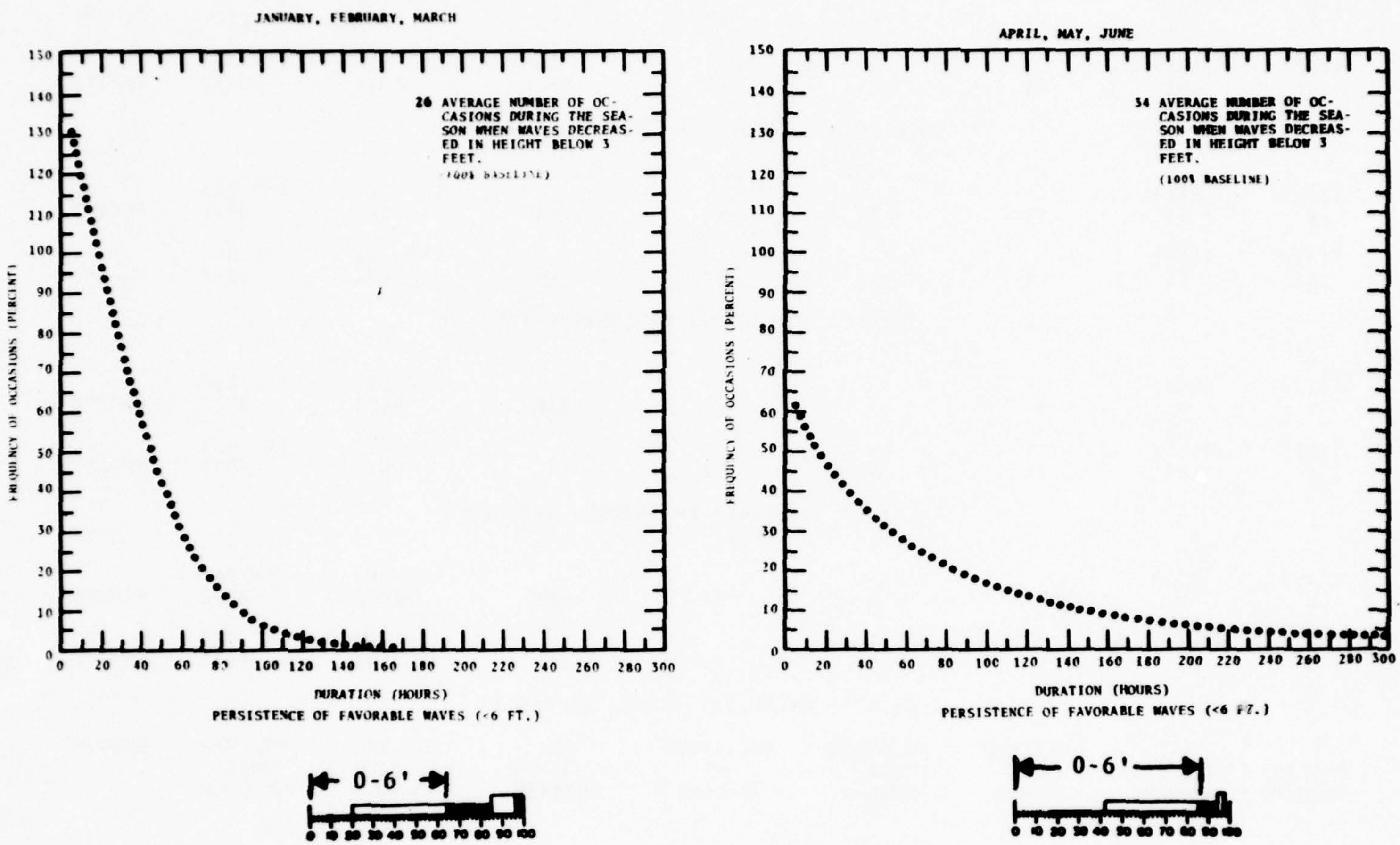


FIGURE 5-1. PERSISTENCE OF FAVORABLE SEAS <6 FEET FOR EAST COAST LIGHTSHIPS: DIAMOND SHOALS, NORTH CAROLINA

TABLE 5-5. PERSISTENCE OF WAVES <6 FT. HIGH

SEASON	ELAPSED TIME HRS (DA)	TOTAL DURATION HRS (DA)	AVERAGE DURATION HRS	NUMBER OF OCCASIONS	NUMBER > AVE. DURATION	NUMBER < AVE DURATION	NUMBER >30 HRS (%)	NUMBER >50 HRS (%)
PORTLAND, MAINE (43°48'N, 70°6'W)								
JaFeMa	2160 (90 da)	1812 (75 da)	75	24	8	16	15 (62%)	11 (46%)
JuAuSe	2208 (92 da)	2060 (86 da)	188	11	3	8	8 (72%)	7 (64%)
NANTUCKET SHOALS, MA (40°37'N, 69°18'W)								
JaFeMa	2160 (90 da)	1750 (73 da)	83	21	4	17	12 (57%)	8 (38%)
JuAuSe	2208 (92 da)	2098 (87 da)	315	7	2	5	6 (86%)	5 (71%)
CHESAPEAKE, VA (36°59'N, 75°42'W)								
JaFeMa	2160 (90 da)	1662 (69 da)	83	20	7	13	13 (65%)	10 (50%)
JuAuSe	2208 (92 da)	2060 (86 da)	159	13	2	11	11 (85%)	8 (62%)
DIAMOND SHOALS, NC (35°05'N, 75°20'W)								
JaFeMa	2160 (90 da)	1382 (57 da)	40	34	15	19	19 (56%)	10 (29%)
JuAuSe	2208 (92 da)	1877 (78 da)	117	16	3	13	10 (62%)	8 (50%)

5.3.4 Surface Current Speed

Surface currents in open water may affect oil spill response operations in two ways. First, in combination with the wind, they determine the direction in which an oil slick will drift. Different response actions may be required if the set of the current is on-shore rather than off-shore. Second, containment and concentration of the oil by curtain barriers is effective only if motion relative to the water does not exceed one knot. Above this speed oil is entrained in the water flow and escapes under the curtain. Thus, in currents under 1 knot booms may be anchored down-current from the source of the spill in order to stop the drifting oil and concentrate it for skimming. Above this speed the boom must be allowed to drift with the current in order to reduce its speed relative to the water.

Tables 5-6 and 5-7 present surface current speed statistics for winter and summer as determined from TDF-11.[5-1] It is clear from these data that currents in excess of 2 knots occur with low frequency and at few locations: occasionally around Cape Hatteras and off the southern portion of the Pacific coast, with an exceptionally high frequency, both winter and summer, between latitudes 38°N to 40°N (sub-region 26). Average speeds are generally under one knot. Prevailing directions vary from offshore along the northern portion of the Atlantic coast to northerly around Cape Hatteras to onshore in the south. Along the Pacific coast the prevailing directions are almost always onshore.

TABLE 5-6. SURFACE CURRENT SPEED STATISTICS
(WINTER)

Area No.	Speed, (kts), percent occurrence 0	0.1-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	$\overline{V}$	Speed, V, (kts) 98%	Prob. Max.	Max. Obs.	Prevailing Direction
4	3	62	28	6	--	--	0.89	2.2	2.8	5.6	SE
5	5	64	27	4	--	--	0.81	2.2	2.8	5.6	SE
6	3	91	4	2	--	--	0.56	2.4	2.9	5.6	SE
7	3	58	33	5	1	--	0.98	2.8	3.7	3.6	N
8	1	49	38	10	2	--	1.15	3.2	4.2	6.0	N
9	2	55	33	8	2	--	1.12	3.2	4.0	5.3	N
10	4	66	26	4	--	--	0.81	2.4	3.3	5.0	W
11	6	68	24	2	--	--	0.75	1.8	2.8	5.0	W
12	5	76	17	2	--	--	0.73	1.9	2.9	5.2	W
13	2	81	16	1	--	--	0.69	1.8	2.3	3.4	W
14	5	75	17	3	--	--	0.70	2.0	2.8	2.6	W
15	<1	79	19	2	--	--	0.73	2.1	2.6	3.6	W
16	3	83	12	2	--	--	0.64	2.0	2.7	3.5	--
17	5	70	21	4	--	--	0.76	2.1	2.7	3.0	SW
18	2	70	26	2	--	--	0.79	2.2	3.0	2.5	NW
19	4	82	12	2	--	--	0.64	2.4	3.0	3.0	NW
22	4	67	24	3	2	--	0.84	3.4	4.1	5.0	SW
24	5	63	22	8	2	--	0.92	3.3	3.9	5.6	NE
25	6	72	19	1	2	--	0.71	3.8	4.5	4.5	NE
26	1	16	23	31	24	5	2.26	5.0	6.0	6.9	N
27	4	57	22	9	7	1	1.13	3.9	4.4	4.5	N
28	1	23	37	32	7	--	1.68	3.5	4.3	5.3	NE
29	6	74	18	2	--	--	0.69	2.1	2.4	5.0	S
30	10	80	8	2	--	--	0.57	2.5	3.1	3.6	S
31	2	87	10	1	--	--	0.61	2.2	2.6	3.0	E

TABLE 5-7. SURFACE CURRENT SPEED STATISTICS (SUMMER)

Area No.	Speed, (kts), percent occurence 0	0.1-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	Speed, V, (kts) $\overline{V}$	98%	Prob. Max.	Max. Obs.	Prevailing Direction
4	4	58	32	5	1	--	0.93	2.6	3.7	4.2	SE
5	4	59	33	4	--	--	0.90	2.3	3.1	3.6	NW,SE
6	4	90	6	--	--	--	0.96	1.6	2.2	6.0	SE
7	3	52	33	10	2	--	1.07	3.2	4.0	5.5	NW
8	4	44	38	12	2	--	1.16	3.6	4.7	5.5	N
9	4	53	32	10	1	--	1.03	2.7	3.2	3.6	N
10	4	66	27	3	--	--	0.97	2.3	3.1	3.6	W
11	8	69	21	2	--	--	0.72	2.1	2.8	6.0	NW
12	7	72	19	2	--	--	0.70	2.0	2.6	3.5	W
13	3	78	19	--	--	--	0.66	1.6	1.9	2.5	W
14	8	68	22	2	--	--	0.92	2.1	2.6	2.5	W
15	3	74	21	2	--	--	0.74	2.1	2.8	2.5	N,W
16	7	87	6	--	--	--	0.52	1.5	2.0	---	-
17	6	61	30	3	--	--	0.83	2.2	2.8	2.8	SW
18	6	83	9	2	--	--	0.60	2.5	3.2	2.6	NW
19	7	79	12	2	--	--	0.62	2.3	3.0	2.6	W,N
22	7	66	24	2	1	--	0.78	3.3	4.4	6.5	SW
24	6	64	19	8	3	--	0.81	3.7	4.2	5.1	SW
25	8	67	22	3	--	--	0.74	2.7	3.2	4.3	NE
26	2	13	19	28	30	8	2.64	4.8	5.5	6.5	N
27	5	57	29	8	6	3	1.26	4.4	5.0	3.0	N
28	1	19	31	34	14	1	2.14	4.0	4.7	5.8	NE
29	9	73	15	3	--	--	0.66	2.5	3.2	4.5	S
30	8	83	9	--	--	--	0.55	2.0	2.4	4.0	S
31	2	86	11	1	--	--	0.62	2.2	2.7	4.0	E

REFERENCES FOR SECTION 5

5-1 Marcus, S.O., Environmental Conditions within Specified Geographical Regions. Off-Shore East and West Coasts of the United States and in the Gulf of Mexico, COM-73-11775 (April 1973).

5-2 U.S. Naval Oceanographic Office, Oceanographic Atlas of the North Atlantic Ocean, Pub. No. 700 (1967).

5-3 Naval Weather Service Command, U.S. Navy Marine Climactic Atlas of the World, Vol. 1 NAVAIR 50-1C-528 (December 1974).

5-4 Petroleum Products Handbook, ed.: V.B. Guthrie (New York, McGraw-Hill, 1955), pg. 8-24, 8-25.

6. EQUIPMENT BASELINE

The equipment required for an effective response to a major oil spill in open water has two major functions - to offload oil before it leaks from a stricken tanker and to recover spilled oil from the surface of the sea. The elements of a complete response system capable of performing these functions are well-defined and consist of:

1. Pumps to offload and transfer oil.
2. Barrier booms to contain and concentrate the spilled oil.
3. Skimmers to recover oil from the surface of the sea.
4. Flexible bags or tank barges as containers to hold the offloaded or recovered oil until it can be transferred to land for disposal.

Many factors enter into the selection of specific items of equipment from among those available to fulfill these functions. Most important among these factors are:

1. Performance characteristics such as capacity, environmental limits, and reliability.
2. Physical characteristics such as size, weight, packaging, and transportability by land, sea, and air.
3. Costs for acquisition, upkeep and maintenance.
4. Auxiliary requirements such as support equipment and operating personnel.

Since some candidate subsystems are still being developed and others have not yet been fully tested under operational conditions, it would be premature at this stage to attempt to make a final selection of all the elements of an effective future response system. For this reason, the Coast Guard has designated the elements of a baseline system as a term of reference for this study. To the extent that they are known, details of these specific items will be presented in this chapter. Other

possible candidates have not been included either because a prototype has not yet been built and tested, or the acquisition, operating and maintenance costs are excessive, or the specified performance appears to be marginal for open water operation.

6.1 POLLUTION RESPONSE SYSTEM ELEMENTS

6.1.1 Offloading

If a tank vessel or tank barge suffers damage or is stranded, it may be necessary to offload oil and/or water in order to refloat the vessel or reduce the quantity of oil that may potentially be released to the environment. Whenever possible, offloading and transfer operations on a tanker casualty are accomplished by the ship's own pumps. Not infrequently, however, onboard pumping systems become inoperable due to flooding so that external pumps are required. These may be available on other nearby vessels, but in many operational circumstances, it is necessary to bring in a portable, self-contained pumping system and place it aboard the damaged vessel.

Typical offloading equipment consists of a prime mover, pump, associated transfer hose, and auxiliary hardware. The pump must be able to handle liquids having a wide range of viscosities, from sea water to heavy crude oil. For water the maximum pumping rate is generally between 500 and 1000 gallons per minute with decreased performance at higher viscosities, large static heads, and long lengths of transfer hose. For the offloading function the baseline system selected by the Coast Guard is the Air Deliverable Anti-Pollution Transfer System (ADAPTS), rated at 1500 gpm. The pump that is used with this system is compatible with a standard 12-inch Butterworth fitting.*

*A Butterworth fitting is a flanged hole in the tanker deck through which a spray nozzle of Butterworth design may be lowered for tank cleaning.

6.1.2 Containment

Containment describes an action taken to limit the continued spreading and migration of oil on the surface of the water or to confine the flow of spilled oil to a small area in the vicinity of the source. It is the critical first step in any controlled and coordinated recovery and clean-up operation.

In open waters physical barriers, or floating curtains, are the most common means of containing oil. These curtains are known as oil containment booms. They also serve to increase the thickness of an oil slick and, as a result, to facilitate recovery operations. Booms designed for use in open water are usually solid, continuous obstructions to the spread and migration of oil. They typically include floats for buoyancy, a skirt for containment, ballast for stability, and a tension member for strength (Figure 6-1).

Oil containment booms are available in many sizes and configurations. Individual lengths can usually be connected with leak-proof joints to form a long, continuous barrier. The boom's free board must have sufficient height and the cross-sectional geometry to prevent oil from washing or splashing over its top. The skirt must be deep enough to prevent oil from draining out from underneath, yet not so deep that the drag forces become excessive. Here there is a tradeoff between the draft required for effective containment of the oil and the drag force produced by that draft. Along with adequate, but not excessive draft, a good boom design will provide reserve buoyancy, roll stiffness, and a strong tension-member.

The containment boom that has been selected by the Coast Guard as best meeting the requirements of this element of the baseline response system is the Open Water Oil Containment System (OWOCS) currently in its inventory. It is packaged in 612 foot lengths and can be delivered to a spill site by air (C-130) or by sea (buoy tender or fast surface delivery sled).

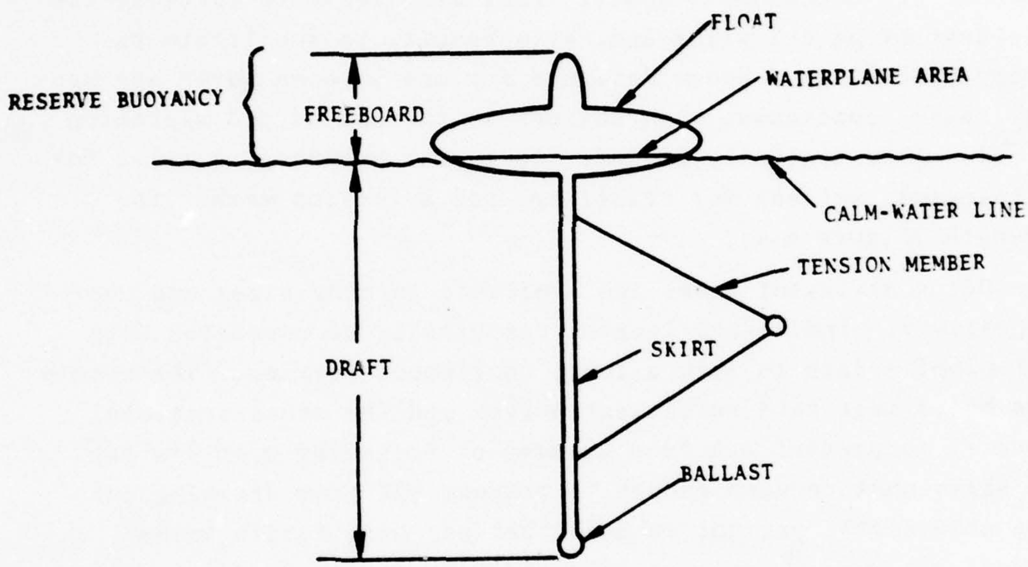


FIGURE 6-1. BASIC ELEMENTS OF A BOOM

6.1.3 Recovery

The second, and perhaps most complex step in the process of removing spilled oil from the surface of the sea is recovery. The most common means available to accomplish this task in open water is by mechanical skimming from the surface. The primary objective of a skimmer is to pick up as much of the oil it encounters together with as little water as possible over a wide range of surface thicknesses, product types, wave heights, currents and debris size and density (including ice). Unlike booms, all skimmers do not operate on the same engineering principles, nor do they all degrade to marginal performance for the same reasons.

6.1.3.1 Skimming Devices - The types of skimmers most commonly used in recovery operations are:

1. Floating weirs
2. Vortex devices
3. Endless belts
4. Suction devices
5. Rotating discs.

Skimmers that use weirs and suction devices tend to pick up a high percentage of water with the oil. Endless belts and rotating discs are more selective in the products recovered and in general, can tolerate higher sea states. However, in rough water the oil may become emulsified or mixed into a watery slurry, in which case little can be done to reduce the total volume of oil and water requiring temporary storage at the spill site.

From these considerations it should be clear that high-performance oil skimmers are complex devices. As a minimum they must (1) pick up a large fraction of the oil they encounter, (2) incorporate some means of separating the recovered oil from water, (3) have the capacity to store the recovered oil temporarily or to pump it off into external storage containers, and (4) be able to operate effectively for many hours in moderate sea states and

debris laden waters. Very few commercial skimmers can meet these requirements.

As the skimming element in its baseline response system, the Coast Guard has selected the Lockheed Disc-Drum Open Water Oil Recovery System (OWORS.) This skimmer is designed to recover more than 90% of spilled product in winds up to 20 knots, 6 foot seas and a 2 knot current. It has a maximum recovery capacity of 1,000 gpm, and requires a tow vessel and a holding barge for the recovered oil.

6.1.3.2 Skimmer-Barrier - Although the baseline response system includes separate barriers and skimming devices, there are a number of inherent disadvantages in the operation of such a system. Subjected to the forces of wind and current, a moored barrier or one being towed by boats takes the open U-configuration of a catenary, and oil entering the boomed area tends to collect at the bend where the curvature of the boom is greatest (the "bucket"). Unless this oil is picked up as it accumulates, the thickness of the oil layer increases until the water flow due to the relative motion of the barrier begins to drain oil from the bottom of the layer and sweep it under the boom. At this point the boom begins to lose oil as quickly as it accumulates, and containment is no longer effective. In a large spill where recovery is limited by skimming capacity, this condition may develop rather quickly.

In order to overcome this difficulty, a barrier-skimmer combination has been developed[6-1] that incorporates a weir skimmer integral with the barrier in the region of maximum oil concentration. By adjusting the speed of the boom through the water to the skimming rate, almost all the oil encountered by the boom can be collected. Skimming is accomplished by connecting a floating pump system to the oil outlets of the integral weir skimmers.

The skimming barrier described above, with six weirs and three pumps, is being developed by the Coast Guard as an element of its baseline open water oil pollution response system. Preliminary tests indicate a flow rate of 600 gpm with a recovery efficiency of 75% at one knot in calm water, dropping to 50% in 1.5 foot waves.

6.1.4 Storage

Oil skimmed from the surface of the sea must be stored in suitable containers for transport to shore and thence to a suitable disposal site. Skimming devices and skimming barriers have no significant storage capacity of their own, and the capacity of available skimming vessels is severely limited. The largest vessel skimmer has a capacity of about 70,000 gals., which is at the lower end of the spill size range considered in this study. Such large vessels would represent a major commitment of resources (3-4 M$ each), yet their oil recovery rates are not greater than those of the devices described above, so they are not an attractive option. On the other hand, interstate tank barges, operated by commercial firms, have capacities as large as a few hundred thousand to a few million gallons. In the event of a massive spill in open water, tank barges or tank ships of this size would be required at the recovery site. However, the time needed to locate an empty tank vessel (or unload one) and bring it to the spill site cannot be time lost to the recovery operation.

To fill this gap the Coast Guard has selected a series of flexible containers called Portable Oil and Hazardous Substance Storage Containers (POHSSC), as the storage element of its response system. These flexible containers are constructed from synthetic rubber coated nylon fabric and cord. They are towable and can be palletized and delivered to the spill site by air. The nominal capacities that will be considered for the Coast Guard inventory are 12,000 gals., 50,000 gals., and 290,000 gals.

6.2 EQUIPMENT CHARACTERISTICS

6.2.1 Pumps

ADAPTS Pump - The ADAPTS pumping system is designed for rapid emergency deployment to remove petroleum base-oils from stranded or otherwise stricken vessels in order to prevent or minimize major oil spills. They may be transported overland by flat-bed trailer or by air on a C-130 fixed wing aircraft, and they can be carried to the spill site and put into the water by helicopter, by buoy tender, or on a Fast Surface Delivery (FSD) planing sled.

Performance Characteristics

Pump performance characteristics are determined by the flow rate through a given length of hose for oil of given viscosity. A graphical method for determining this flow rate is shown in Figure 6-2. Curve (a) of this figure represents the typical performance of a pump, giving the flow rate as a function of the discharge head (or pressure) for a particular fluid viscosity. Curve (b) shows the discharge hose characteristic for the same fluid and for a specified length of hose, corrected for the static pressure difference between inlet and outlet. When these two curves are superimposed, as in (c), their intersection yields the flow rate for the particular combination of pump, hose, and viscosity.

Characteristic curves for the ADAPTS two-stage submersible pump are shown in Figure 6-3 for a range of viscosities from 1 to 3300 centistokes (cs.) or from water to viscous No. 6 residual. It can be seen that for a given discharge head the flow rate decreases rapidly when the viscosity is greater than 500-1000 centistokes. The corresponding dynamic pressure drop curves for three lengths (100 ft, 200 ft, and 300 ft) of ADAPTS hose are shown in Figures 6-4 to 6-6. With the method of Figure 6-2, these curves may be used to determine ADAPTS pumping rates for a variety of conditions. Some specific examples are shown in Figure 6-7.

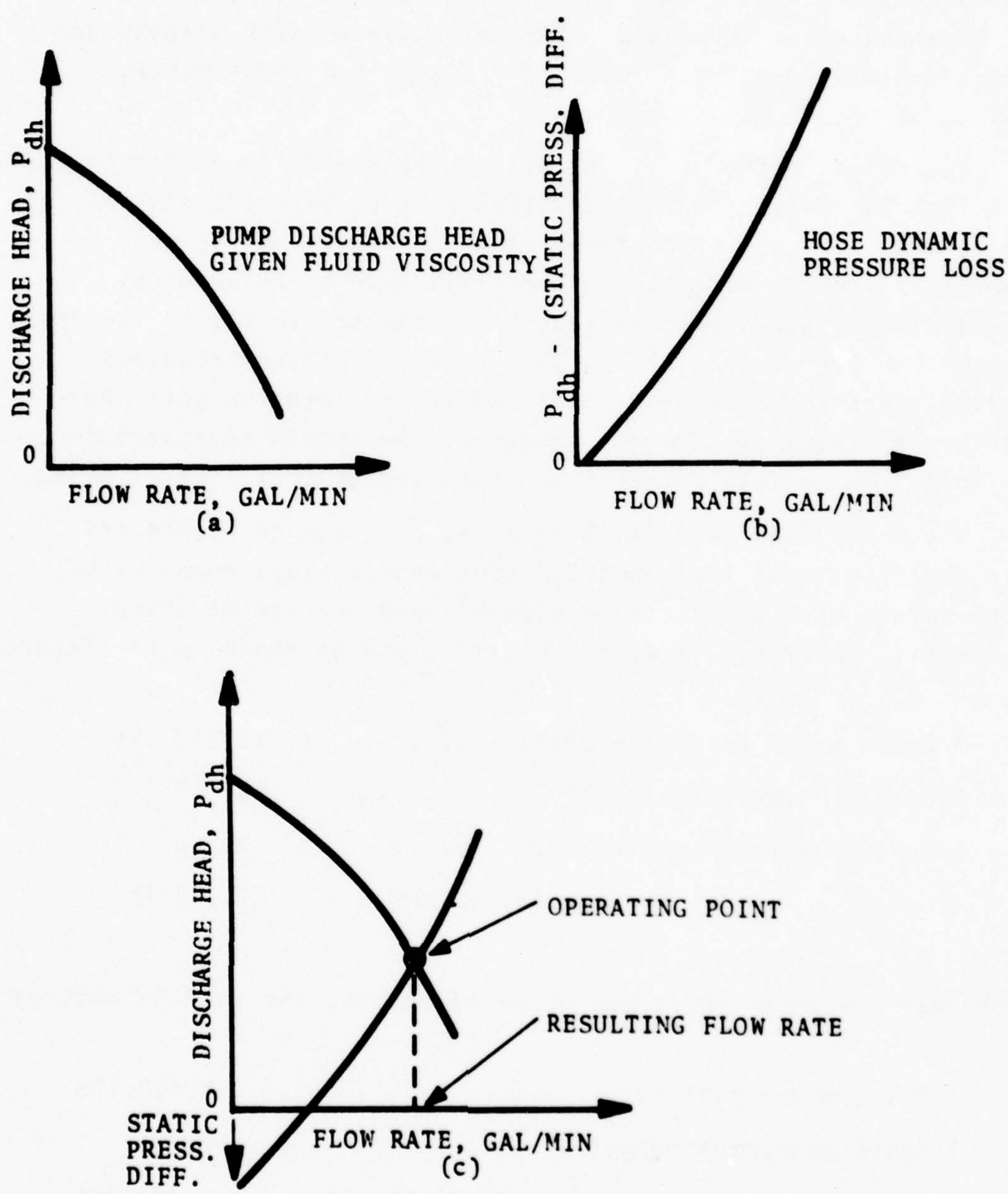


FIGURE 6-2. GRAPHICAL DETERMINATION OF PUMPING SYSTEM OPERATING POINT

Physical Characteristics

The ADAPTS pumping system consists of five basic components together with a set of support equipment needed for its operation and maintenance in the field. The major items, with weights and dimensions are listed in Table 6-1. Figure 6-8 is an outline drawing of the double stage pump.

The normal method of transporting the ADAPTS is either by road on a flatbed trailer to a debarkation port or by C-130 aircraft to the nearest airport. From the airport, delivery may be made by truck to vessel or directly to the spill site by helicopter. Should circumstances require it, ADAPTS can be brought to the spill site by the FSD planing sled. This mode of delivery requires special flotation packages, which add to the total weight. For delivery by truck or aircraft, however, the ADAPTS equipment is pre-loaded on pallets suitable for handling by fork lift or crane.

The C-130 load plan, with weights, is shown in Figure 6-9. Note that the total load includes four double stage pumps, four prime movers with associated equipment, and one set of spare equipment. Therefore, a complete C-130 load as shown in the figure is:

4 Prime mover pallets @ 3953................	15,812 lbs.
1 Double stage pump pallet..................	4,059
1 Spare equipment pallet....................	2,398
Total weight	22,269 lbs.

With only one prime mover and a set of spares, the load is reduced to:

1 Prime mover pallet..........................	3,953 lbs.
1 Spare equipment pannel......................	2,938
Total weight	6,351 lbs.

This load includes only one single stage pump.

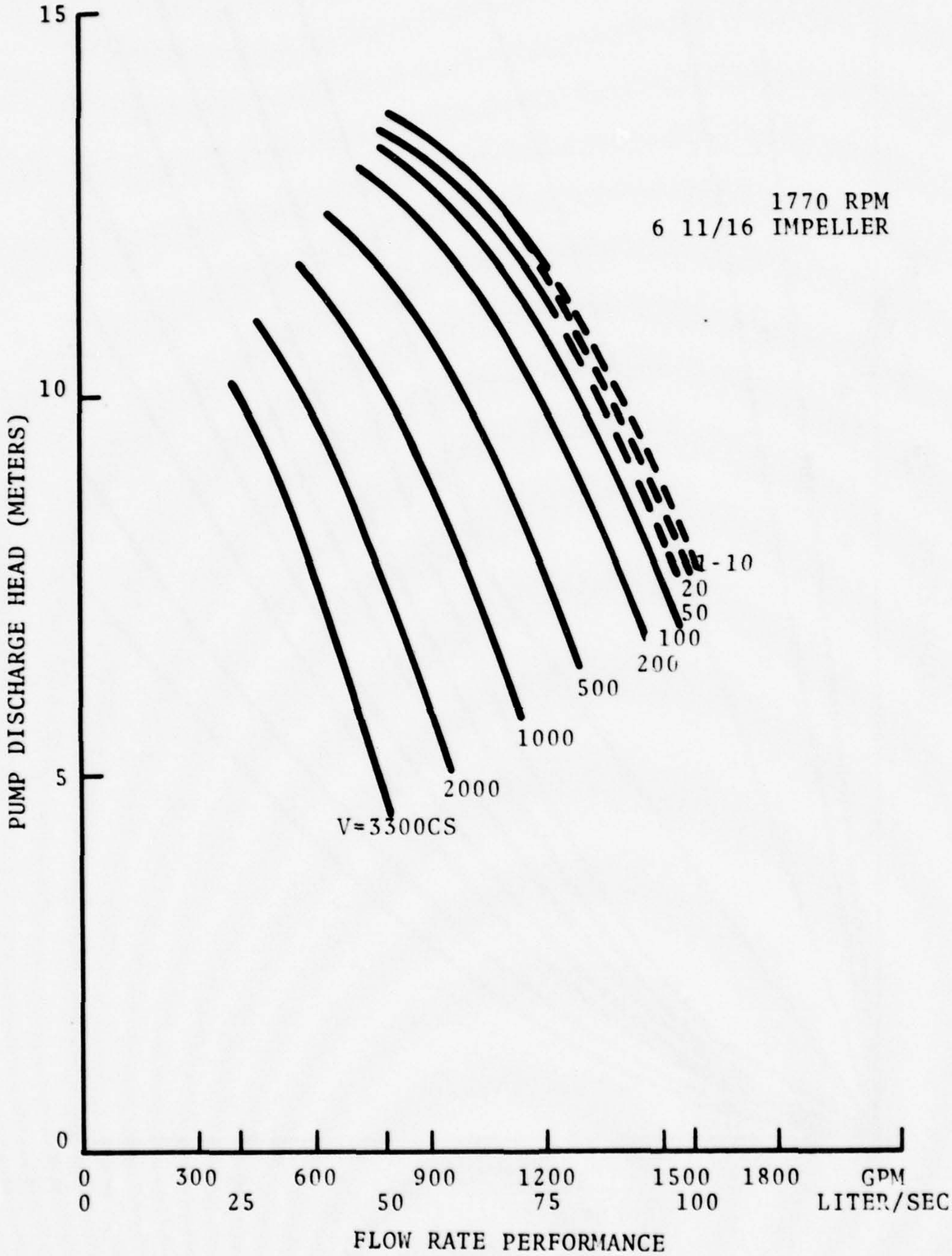


FIGURE 6-3. ADAPTS TWO-STAGE PUMP PERFORMANCE

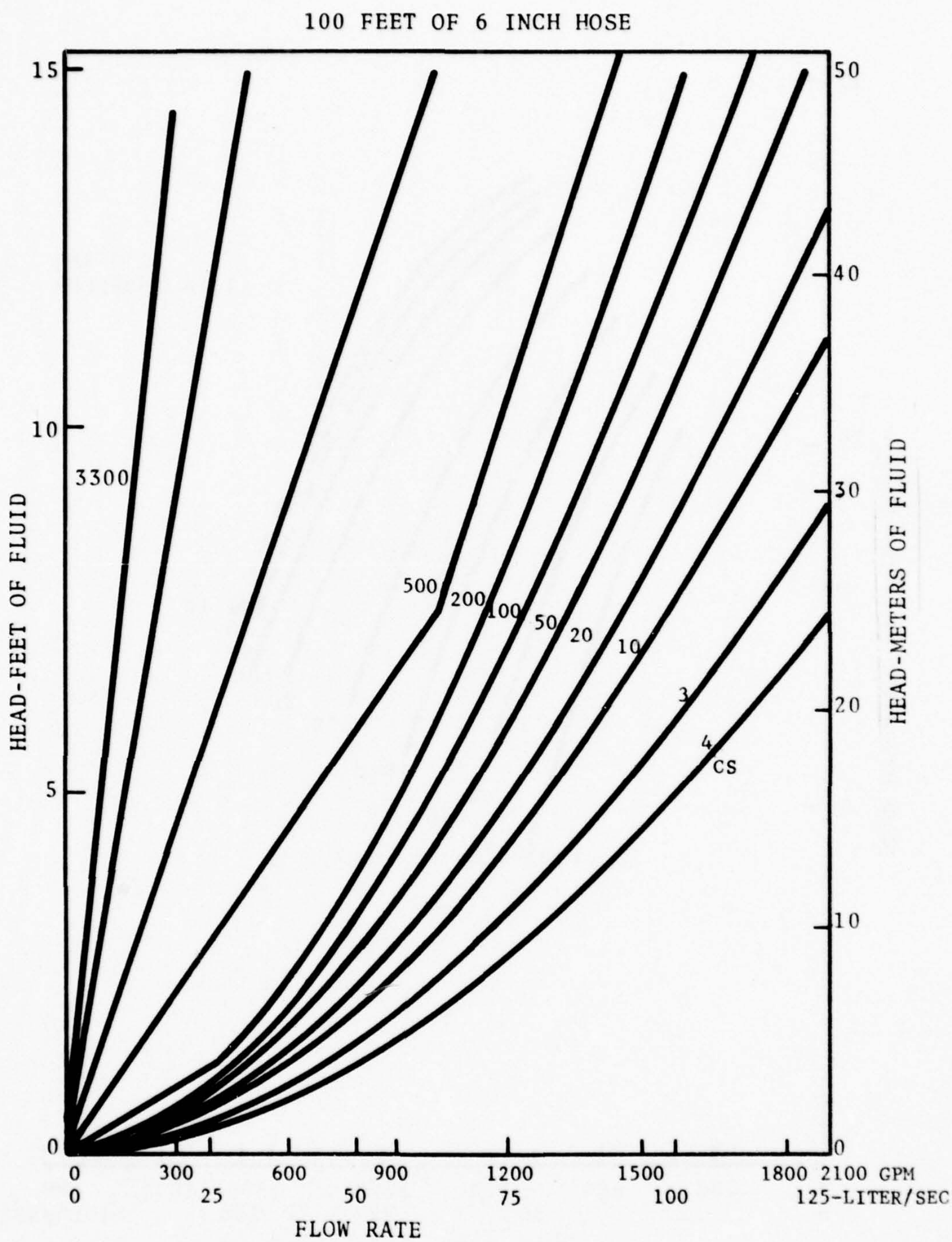


FIGURE 6-4. DYNAMIC PRESSURE DROP IN ADAPTS HOSE - 100 FT

200 FEET OF 6 INCH HOSE

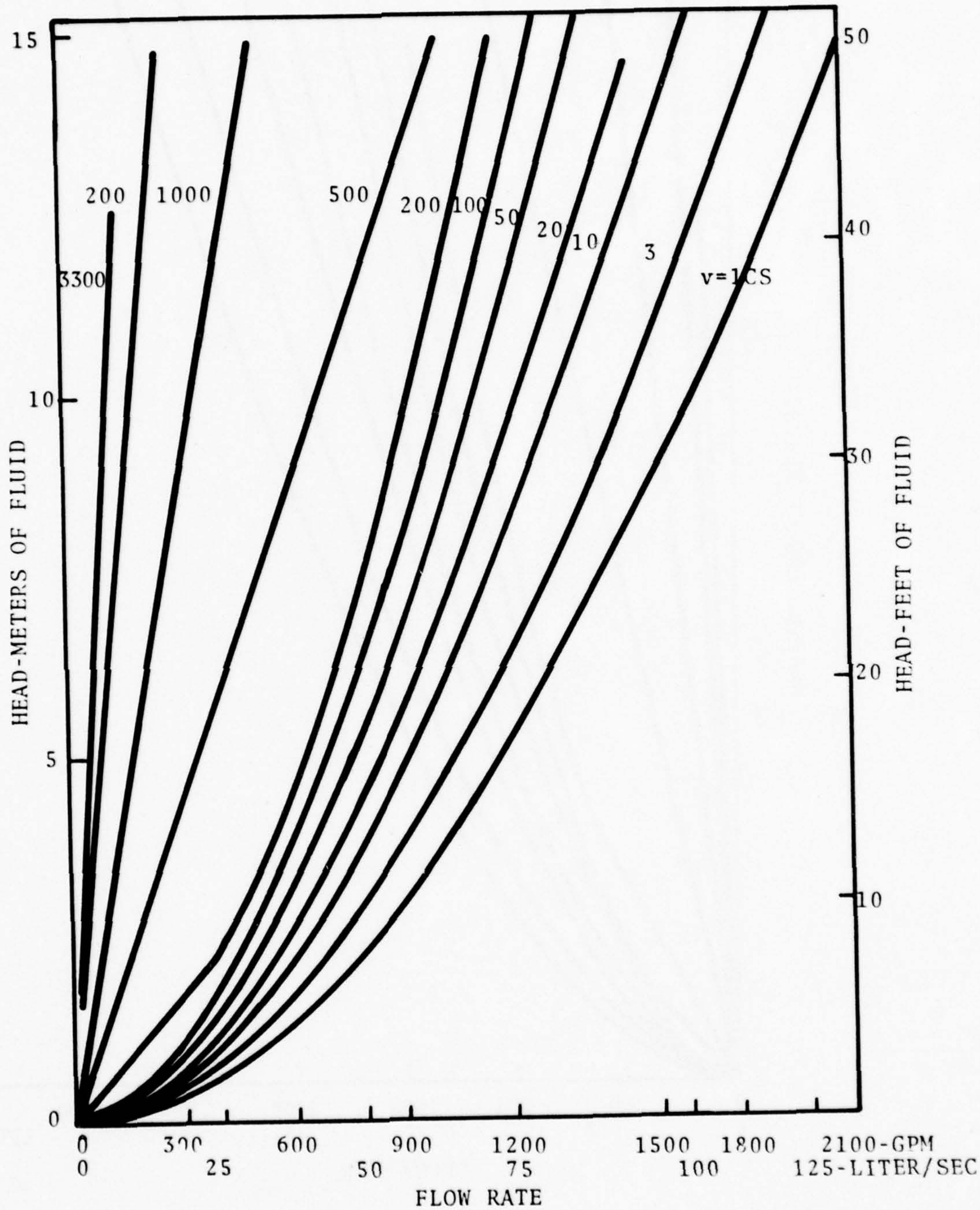


FIGURE 6-5. DYNAMIC PRESSURE DROP IN ADAPTS HOSE - 200 FT

300 FEET OF 6 INCH HOSE

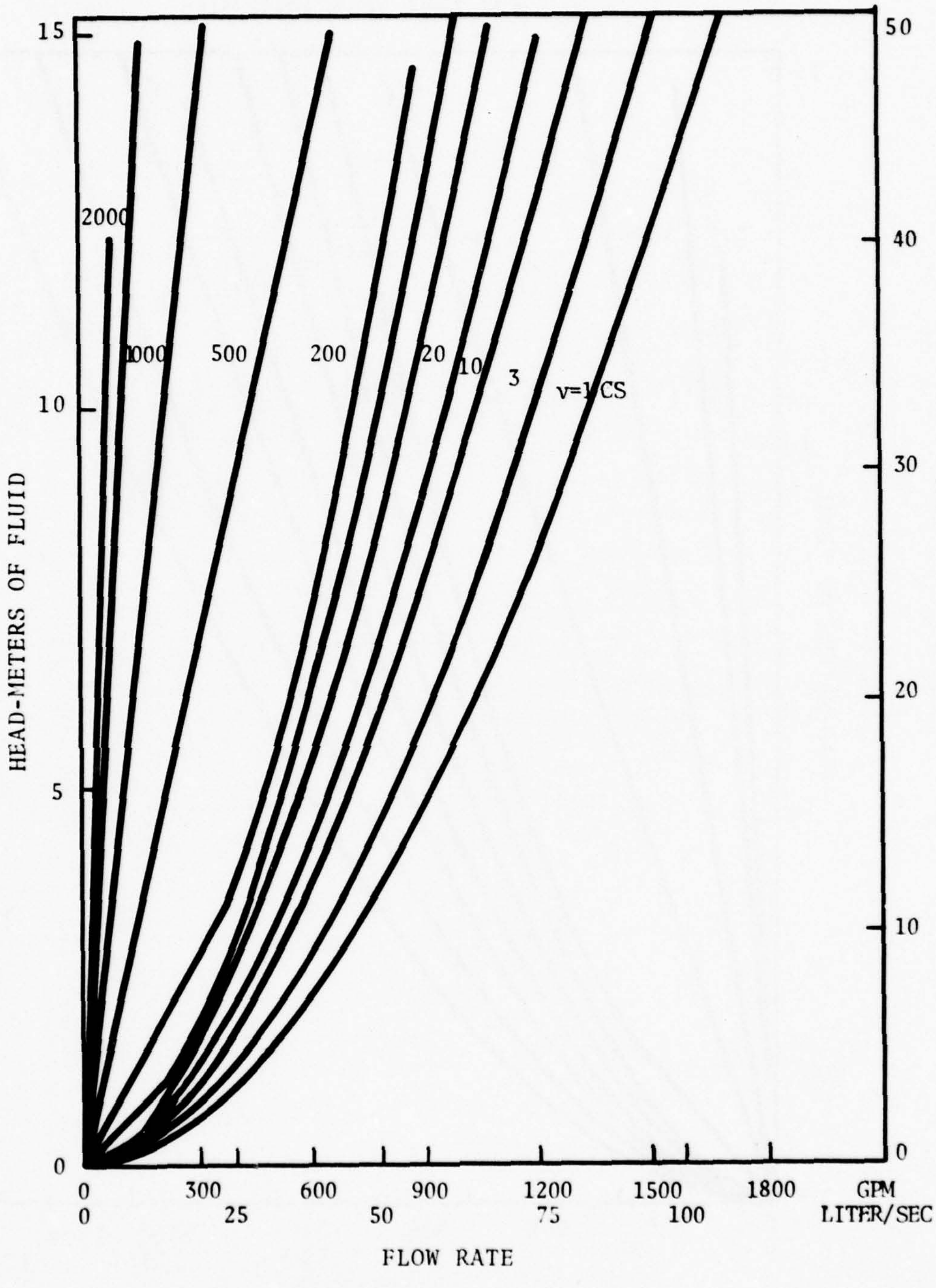
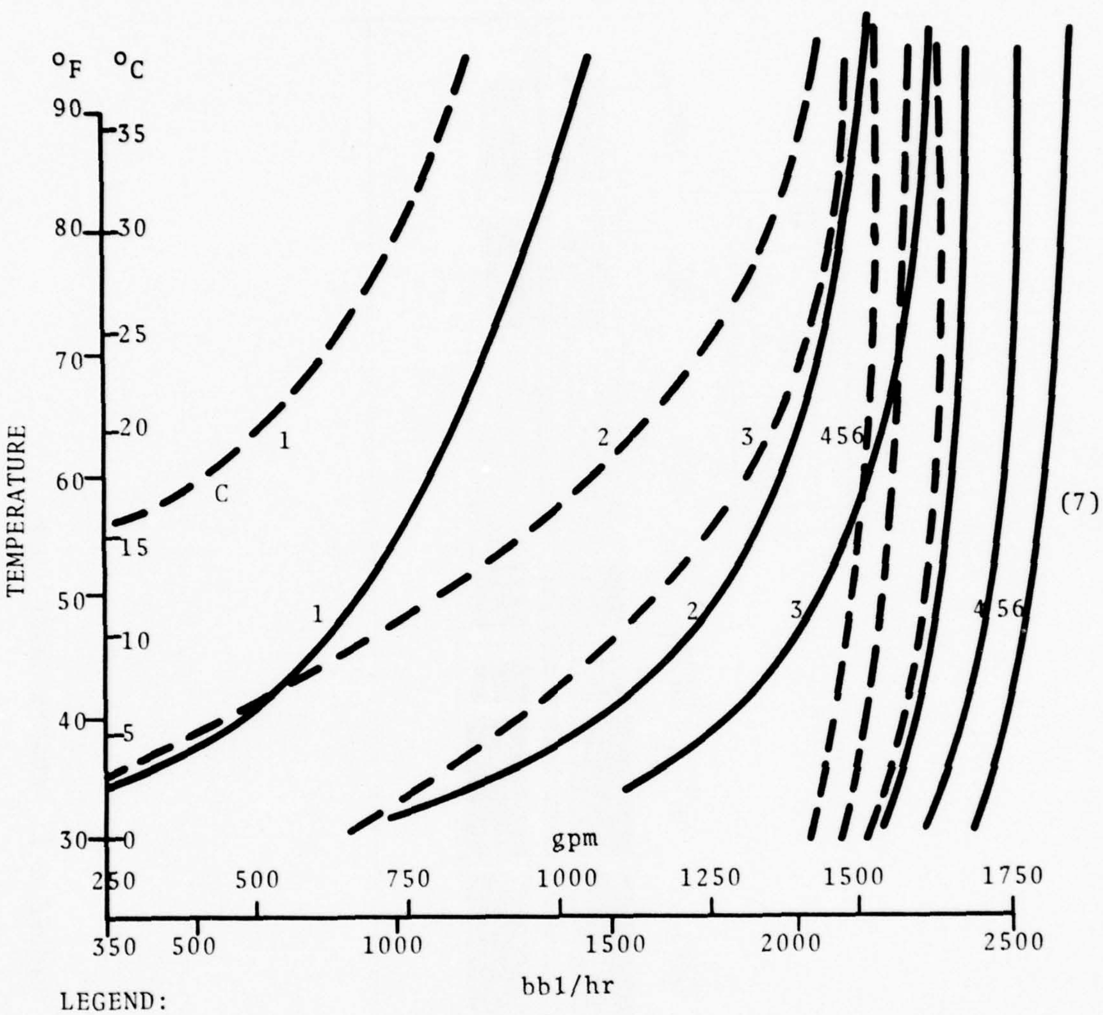


FIGURE 6-6. DYNAMIC PRESSURE DROP IN ADAPTS HOSE - 300 FT

ADAPTS PUMPING RATES



LEGEND:

SINGLE STAGE & STRIPPER PUMP

DOUPLE STAGE PUMP

Baseline Geometry
35' Head
300' hose

1 - BUNKER "C" (HEAVY BLACK FUEL OILS,
2 - LIGHT FUEL OILS AND LUBE OILS
3 - SANTA BARBARA CRUDE
4 - PRUDHOE BAY CRUDE
5 - DIESEL AND NO 2 FUEL OIL
6 - KEROSENE AND JET FUELS
7 - WATER AND GASOLINES IN EXCESS OF 200 gpm (2800 bbl/hr)

FIGURE 6-7 ADAPTS SYSTEM PERFORMANCE

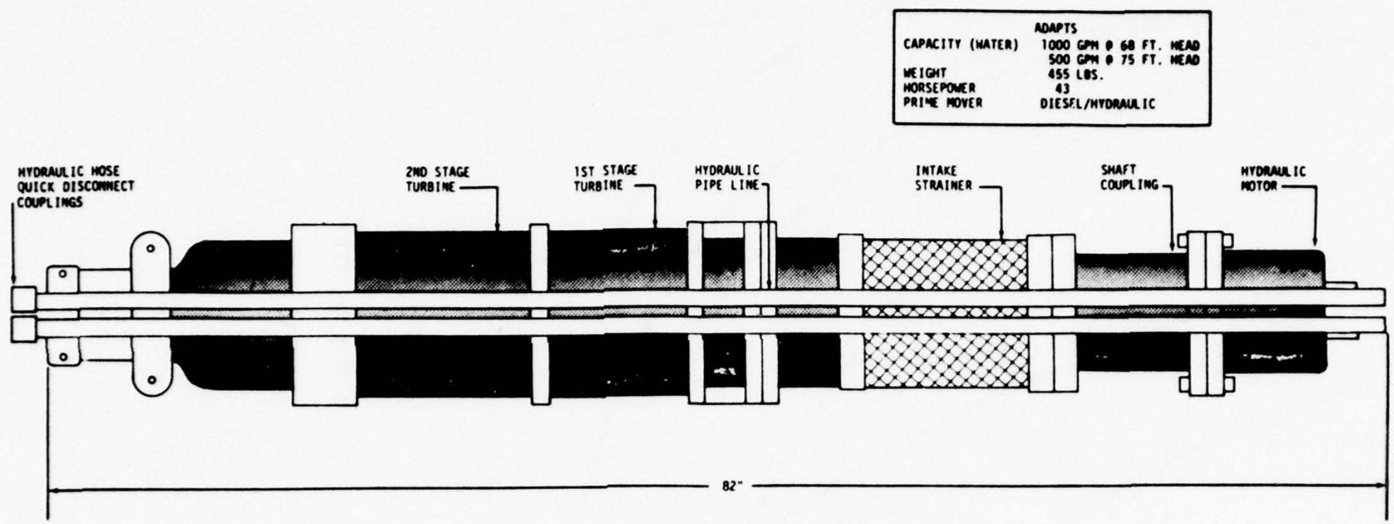


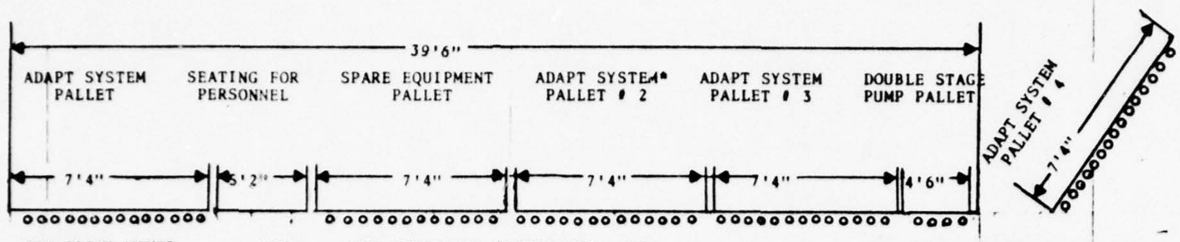
FIGURE 6-8. ADAPTS CARGO PUMP

TABLE 6-1. ADAPTS EQUIPMENT SUMMARY [REFS 6-2 AND 6-3]

ITEM	WEIGHT (LBS)	DIMENSIONS (INS.)	VOLUME (CU. FT.)	($)COST**
Diesel/Hydraulic Prime Mover	1122	41"x34"x44"	35.5	31,000
Submersible Double Stage Pump	896	20 x20 x113	26.1	10,000
55 GAL. Fuel Container	460	36 x24 diam	9.4*	200
Tripod Module	190	98 x14 diam	8.7*	2,000
6 Sections 50'x6" Discharge Hose	720	36 x 36 x 72	54.0	600 per section
Submersible Single Stage Pump	340 w/box	20 x 18 x 66	10.9	8,000
Submersible Stripping Pump	370 w/box	20 x 18 x 66	13.8	8,500
Tripod Rigging Gear	200	14 x 32 x 17	4.4	2,000
Universal Flange Kit	290	14 x 48 x 26	10.1	300
Spare Parts	500	14 x 32 x 17	4.4	100
Tool Box	85	11 x 18 x 11	1.3	200
Flowmeter	230	16 x 25 x 30	6.9	
600' Hydraulic Hose (6 lengths)	810	28 x 28 x 48	21.8	
Hydraulic Oil (5 GALS)	46	20 x 14 x 7	1.1	40
Lubricating Oil (5 GALS)	45	20 x 14 x 7	1.1	20
Dual Rail Pallets ea.	290			

*The fuel module is a collapsible rubber coated fabric container for #2 Diesel. The operating time on one tank-full is approximately 18 hours.

**Procurement costs are best estimates, where available, in 1976 dollars.



ONE PRIME MOVER	1122
ONE TRIPOD	190
ONE TRIPOD RIGGING BOX.	200
ONE FUEL CONTAINER	460
SIX DISCHARGE HOSES	
120 lbs. x 6=	720
5GAL. HYDRAULIC OIL	46
FOUR HYDRAULIC HOSES	
135 lbs. x 4=	540
ONE SINGLE STAGE PUMP	340
5 GAL. LUBE OIL	45
DUAL RAIL PALLET	290
	3953

ONE UNIVERSAL FLANGE KIT	290
ONE METRIC TOOL BOX	85
SIX HYDRAULIC HOSES	
135 lbs. x 6	810
THREE STRIPPING PUMPS	
370 lbs. x 3	1110
ONE FLOW METER (TWO) BOXES	
TURBINE BOX 165 lbs.	
METER BOX 65 lbs.	240
FOUR SPARE PARTS BOXES	500
FUEL RAIL PALLET	290
	2398

FOUR DOUBLE STAGE PUMPS	3584
FOUR STACKING RACKS	300
MODIFIED FUEL RAIL PALLET	175
	4059

*NOTE: ADAPT PALLETS SYSTEM NUMBER TWO THREE AND FOUR ARE THE SAME AS NUMBER ONE.

FIGURE 6-9 C-130 LOAD PLAN FOR AIR DELIVERABLE ANTI-POLLUTION TRANSFER SYSTEM

6.2.2 Containment Booms

Coast Guard Open-Water Boom - The Coast Guard open water containment boom is a barrier with a 27 inch draft and a 21 inch freeboard. It is packaged in sections 612 feet long and weighs 16 lbs. per foot. The barrier is maintained at the proper level and orientation on the surface of the water by 102 flotation bags, inflated during deployment by individual CO_2 cylinders. It is designed to contain oil in a 20 knot wind, 4-6 foot seas and 1-2 knots of current.

The packaged boom can be transported by C-130 aircraft, or over the road by truck. For water transport to a spill site, either a buoy tender (with crane) or an FSD planing sled may be used. At the spill site deployment may be from a vessel or in the water from the container.

Performance Characteristics

The ability of an oil boom to concentrate oil for recovery depends in large measure on the loss rate of the barrier. No open water data are available for this exact barrier configuration, but a similar design, differing primarily in that it had floats on the oil side as well as the back side, was tested at Point Conception, California, on March 8 and 10, 1972, using Soybean oil. (Ref. 6-4) At relative speeds in the range 0.71 - 0.77 knots, the loss rate in calm water was less than 1 gallon/min out of 24,000 gallons. These losses were due mainly to agitation by the interior floats, which have been removed in the most recent design. At a speed of about 1.06 knots, the loss rate in calm water was about 50-70 gal/min out of about 22,000 gallons, primarily from the headwave. Finally, as towing speeds increased to 1.6 knots the loss rate in calm water increased to about 680 gal/min.

In rough water (about 2 feet significant wave height, swell of 8 feet with a ten second period), the loss rate was about 35 gal/min out of 5,700 gallons contained at an average speed of 0.4 knots. At an average speed of 0.6 knots the loss rate was 70 gal/min with about 4,000 gal contained. At 1.6 knots the loss rate

was 200 gal/min with 1300 gallons contained. At the lower speeds (.35 knots) air bag agitation was responsible for almost all losses; at intermediate speed (0.6 knots) it was responsible for about 60% of the losses, the remainder being due to headwave droplet entrainment and orbital velocity; at high speeds (1.0 knots and above) the losses are almost all due to entrainment at the headwave. Table 6-2 summarizes the results.

TABLE 6-2. RESULTS OF PT. CONCEPTION TESTS OF USCG BARRIER, 1972(1)

	SPEED (kts)	AM'T IN BOOM (gal)	LOSS RATE (gal/min)	LOSS MECHANISMS
Calm Water				
	0.71-.77	24,000	1.0	float agitation
	1.06	22,000	50-70	headwave
	1.6	9,400	680	headwave
Rough Water (2 ft. waves, 8 ft. swells with 10 sec period)				
	0.4	5,700	35	float agitation
	0.6	4,000	70	60% float agitation 40% headwave
	1.6	1,300	200(2)	headwave

NOTES: (1) Tests performed with soybean oil (similar to No. 4, or to a typical crude).

(2) This rate was independent of amount in boom.

(3) No substantial drainage losses occurred.

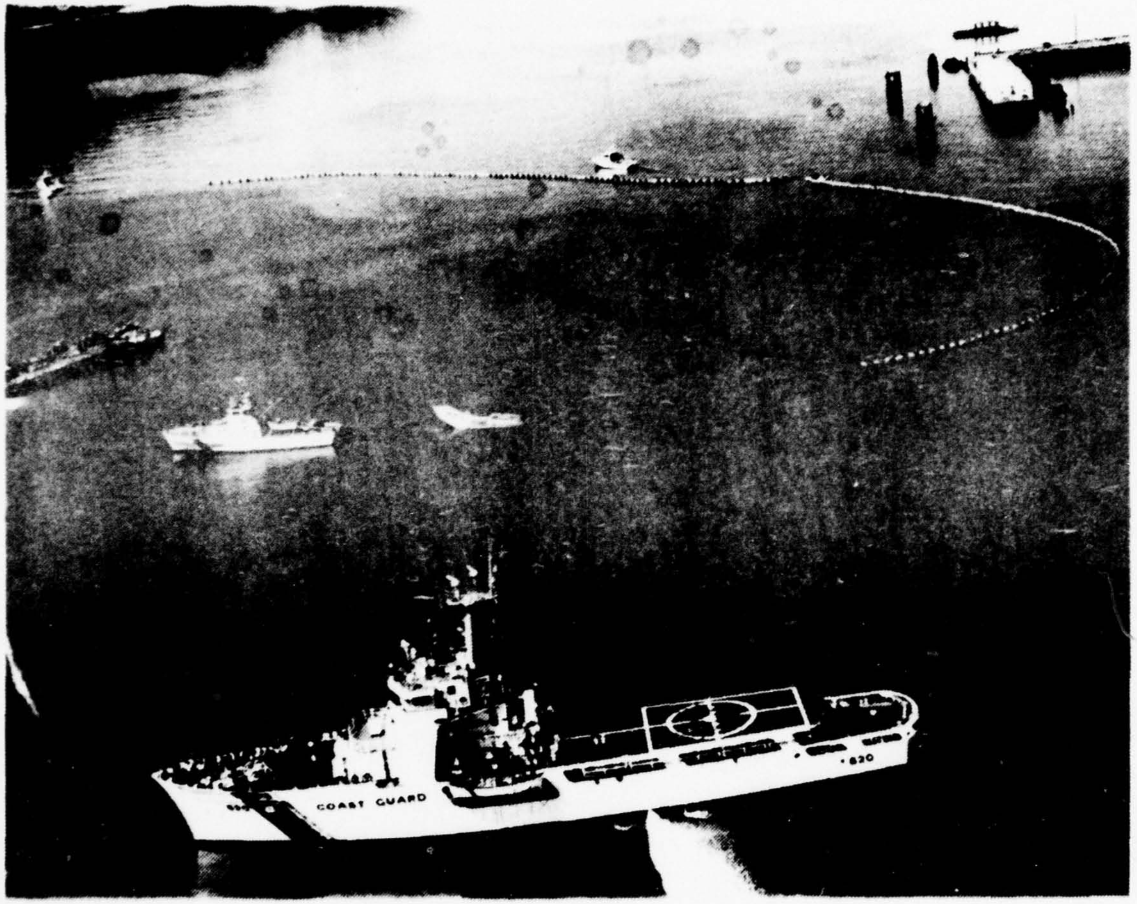


FIGURE 6-10. COAST GUARD BOOM DEPLOYMENT FROM A FAST SURFACE DELIVERY (FSD) PLANING SLED.

Physical Characteristics

The physical characteristics of the Coast Guard open water boom are given in Table 6-3.

TABLE 6-3. COAST GUARD BASELINE BARRIER

Section length:	612 ft.
Draft:	27 in.
Freeboard	21 in.
Material:	Two ply nylon fabric with elastomer coating
Tensile strength:	50,000 lbs.
Flotation:	102 flotation bags inflated by individual CO_2 cylinders
Ballast:	.
Packaging:	Air deliverable container with positive buoyancy.
Package size:	Length, 18 ft.; width, 9 ft.; height, 5 ft. 5 in.
Package weight:	15,265 lbs.
Limiting conditions:	Wind 20 kts Waves 4-6 ft. Current <2 kts
Test results:	See Table 6-2.
Cost:	$100,000 with crate (approximate, 1976 dollars)

6.2.3 Skimming Barrier and Skimming Devices

6.2.3.1 Coast Guard OWOCRS, Open Water Oil Containment and Recovery System - The skimming barrier and pumping system being developed by the U.S. Coast Guard[6-1] is a modification of the baseline containment boom previously described. The skimmer that was integrated into the boom design is a simple weir skimmer consisting of a partly submerged slot in the barrier curtain through which oil and some water pass and fall into a sump tank on the other side from which it is pumped. The prototype design, containing 6 weirs and 3 floating pumps with 2 inlets each, was tested at the EPA's OHMSETT facility with respect to oil recovery and in sea trials off Florida for operational practicality. Although the system has not yet entered the Coast Guard inventory, it may be considered state-of-the-art and shows promise for the future.

Performance Characteristics

In the OHMSETT tests the recovery efficiency (oil/(oil + water)) of the skimmer portion of the boom-skimmer combination was found to be as high as 76% in calm water and as low as 24% in 1.5 ft waves. The results of the OHMSETT tests are summarized in Table 6-4. No tests have yet been performed in open water of the skimming barrier under tow using a suitable oil substitute.

Physical Characteristics

Although no production models of the skimming barrier are available as yet, it is expected that their physical characteristics will be closely similar to those of the open-water boom alone (Table 6-3).

6.2.3.2 The Lockheed Open Water Skimmer (Ref. 6-5) The Lockheed skimmer is a disc-drum recovery system that consists of an oil recovery drum mounted in a captive catamaran. The catamaran hull consists of 4 large inflatable pontoons which support a rigid midships section that contains the oil collection disc-drum, oil

TABLE 6-4. RECOVERY EFFICIENCY OF OPEN WATER OIL CONTAINMENT SYSTEM WITH SKIMMING WEIRS, OHMSETT TESTS

	SPEED kts	PUMPING RATE gal/min	RECOVERY RATE gal/min	RECOVERY EFFICIENCY %
Calm Water	1.0	697	530	76
Rough Water (1.5 ft waves, 6 second period)				
6 sec. period	1.5	626	264	42
6 sec. period	0.75	436	216	50
3 sec. period	0.75	325	134	41
3 sec. period	1.5	594	145	24

NOTES: (1) Tests employed SAE 40 oil and No. 2 fuel oil.
(2) Slick thickness from 1 inch to 4 inches.
(3) See Reference 6-1 for details.

transfer pumps, and hydraulic oil and fuel tanks. The skimmer is secured to the Open Water Oil Containment System and is designed to be operated unmanned as it floats on the pool of oil inside the barrier. With pontoons deflated, the skimmer can be transported by trailer-truck and aircraft from its storage site to a debarkation port for loading on a support vessel such as a 180 ft buoy tender. The prime mover on the prototype is an 88.5 hp. marine diesel engine which drives two hydraulic oil transfer pumps; a third pump drives the oil recovery system. Specifications for the skimmer require the ability to withstand seas with an average wave height of 10 ft in a 40 knot wind at a speed of 5 kts relative to the water.

Performance Characteristics

The recovery system has a capacity of 1000 gpm with a recovery efficiency of 90% in a 20 kt wind 6 ft seas, and a 2 kt. current. The recovery rate is a function of slick thickness, and detailed performance projections may be found in Reference 6-5. Typical performance in a slick 4 inches thick is shown in Figure 6-11.

Physical Characteristics

TABLE 6-5. OWORS PHYSICAL CHARACTERISTICS

Dimensions:	Deflated - 7'x28'x8.5'
	Inflated - 26'x28'x11.5'
Weight:	15,000 - 17,000 lbs.
Max. Operating Conditions:	Wind 20 kts
	Waves 6 ft
	Current 2 kts
Max. Survival Conditions:	Wind 40 kts
	Waves 10 ft
	Current 5 kts
Cost:	$800,000 (approximate, 1976 dollars)

6.2.4 Containers

6.2.4.1 The Dunlop Dracone Flexible Container - To provide storage for offloaded or recovered oil pending the arrival at the scene of large lightering vessels, the Coast Guard has selected a series of containers as the storage element of its baseline response system. These containers are listed with their basic characteristics in Tables 6-6 and 6-7.

In normal use the bag is packed on a pallet and taken to the response site on a buoy tender or planing sled. The empty bags have positive buoyancy so that they remain afloat during deployment. If a bag is to be towed, it is filled to no more than 85% of design capacity in order to keep the dynamic stresses below design limits in the presence of wave action. The fact that the bag is almost completely submerged renders it relatively immune to sea states and winds while moored at the site or while under tow. The bag does, however, present a fairly high drag force and cannot be towed at speeds in excess of a few knots without risk of damage.

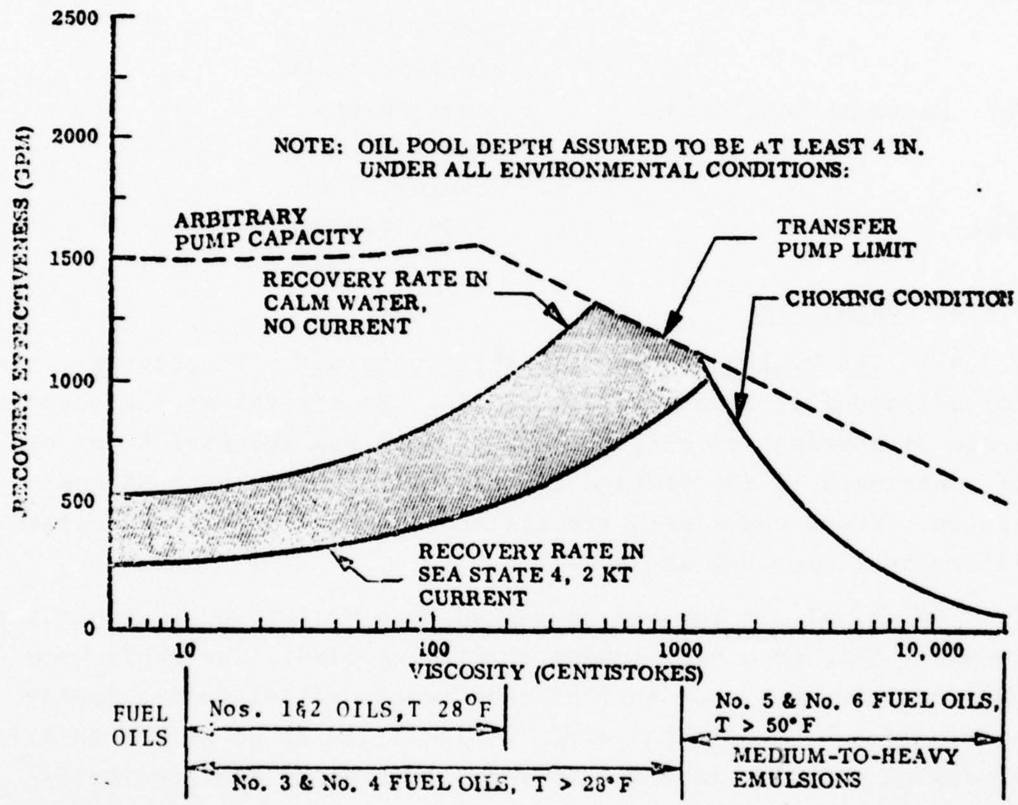


FIGURE 6-11. OWORS DISC-DRUM PERFORMANCE CREWS

Performance Characteristics

TABLE 6-6. BASELINE STORAGE BARGES, CAPACITIES

Dracone Type	OW	F	D10
Nominal Cap. (gals.)	290,400	50,400	12,000
97% Load (gals)	282,000	48,900	11,600
at wave height (ft)	≤ 7	≤ 4	≤ 2.5
85% Load (gals)	246,800	42,800	10,200
at wave height (ft)	>7	>4	>2.5

The physical characteristics of the three baseline barges are given in Table 6-7. Figures 6-12 and 6-13 show the tow-line tension and drag horsepower requirements under tow. The drag of the empty bag with buoyancy tubes inflated is approximately 75% of the drag when filled.

Physical Characteristics

TABLE 6-7. BASELINE STORAGE BARGES, PHYSICAL CHARACTERISTICS

	Dracone Type		
Packaged	OW	F	D10
Length	19'2"	12'3"	9'2"
Width	6'4"	5'4"	5'4"
Height	5'10"	3'5"	3'5"
Volume (cu. ft.)	709	223	167
Weight (lbs)	13,104	8,064	3,052
Deployed			
Length	260'	160'	100'
Diameter	13.8'	7.4'	4.5'
Weight (lbs)	9521	5016	1638
Max Draft	11.8'	6.25'	4.23"
Cost*	$236,300	$85,650	$36,000

*These costs are in 1976 dollars. Approximately 35% must be added to convert to 1979 dollars.

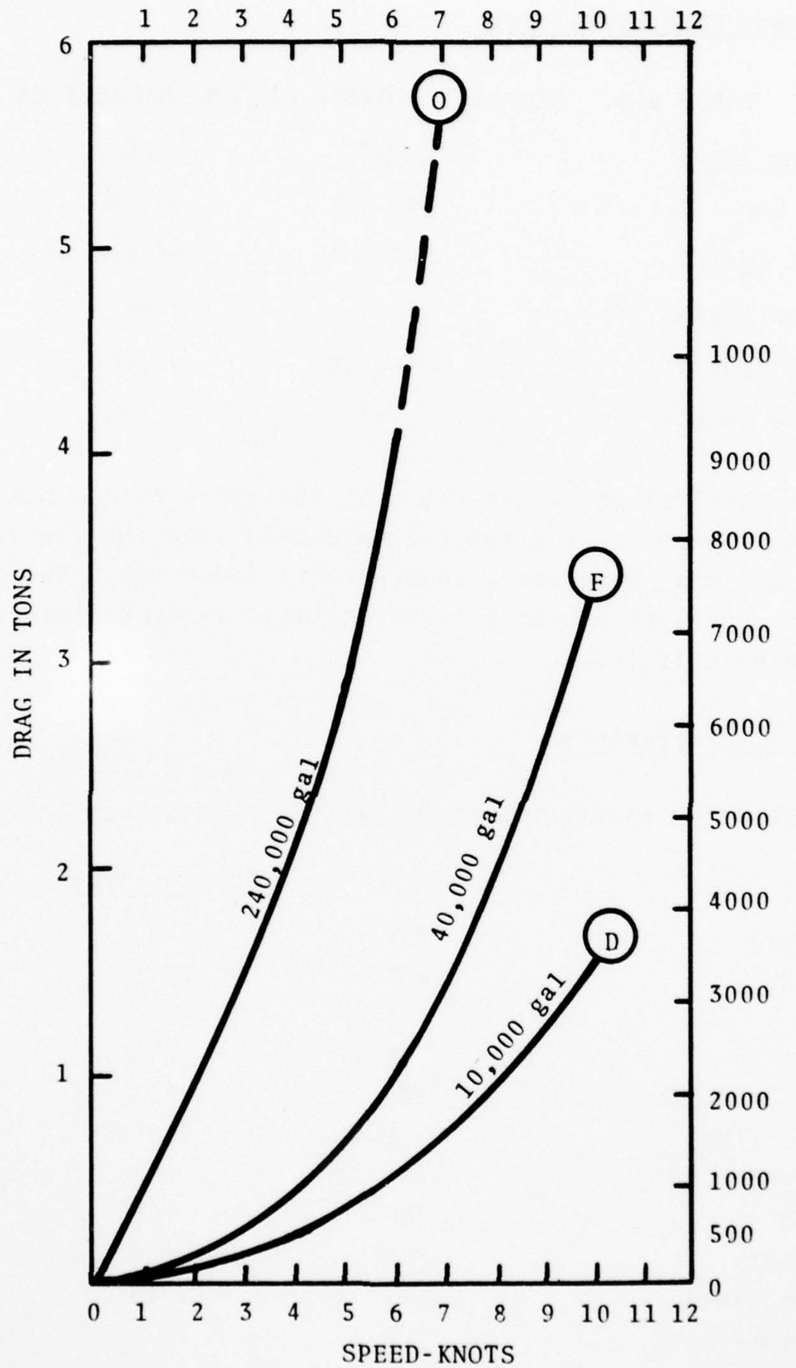
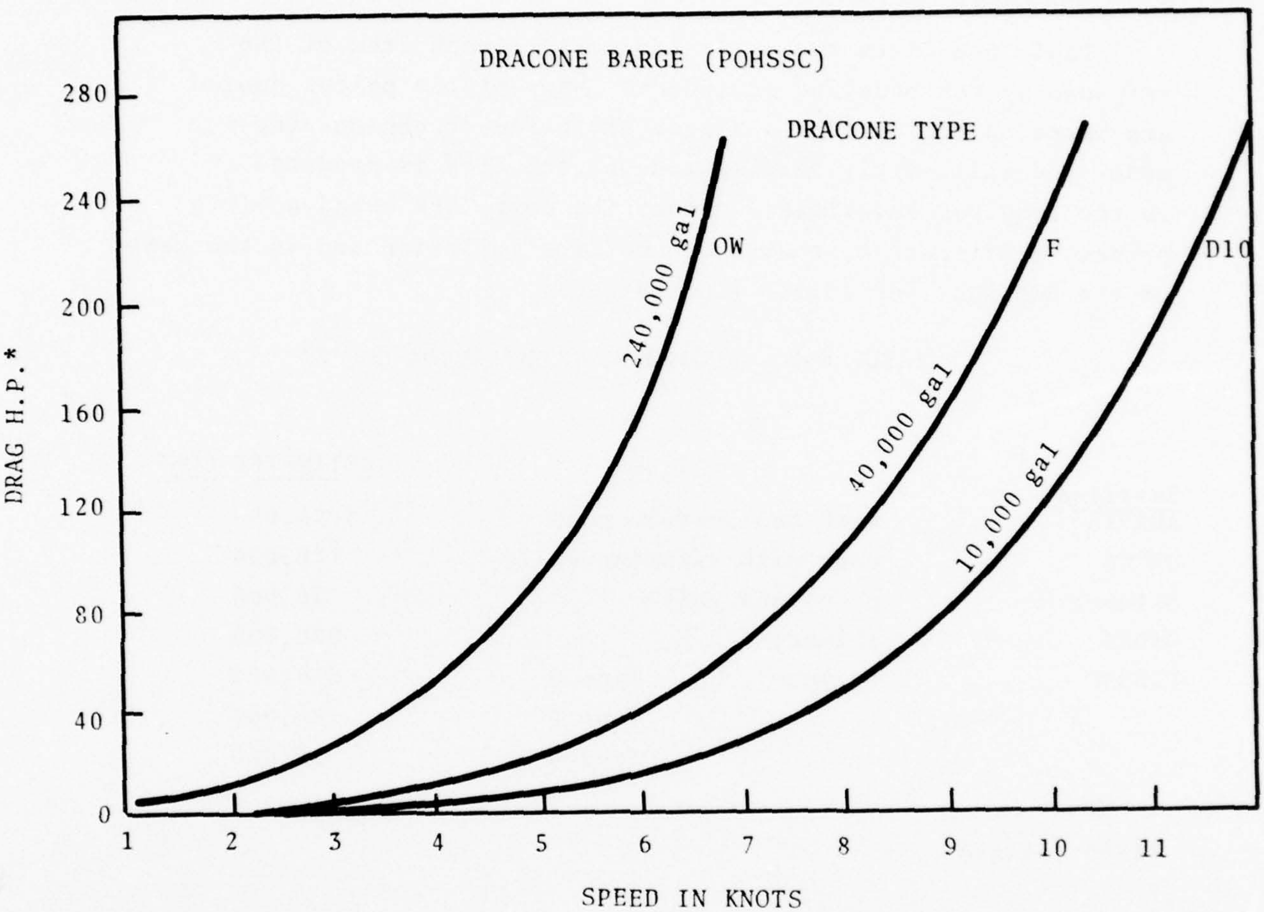


FIGURE 6-12. CURVES OF LINE TENSION



*To convert LBS. DRAG x KNOTS to DRAG HORSEPOWER multiply by 1/330.

FIGURE 6-13. CURVES OF DRAG HORSEPOWER

The expected draft as a function of product carried is shown in Figure 6-14.

6.3 EQUIPMENT COSTS.

Table 6-8 lists the estimated cost of each item of the response system baseline equipment. Many of the prices quoted are based on the cost of a single prototype or engineering model and will surely be different if the item is produced in the required quantities. Since the costs are based on 1976 prices adjustments must also be made for inflation and in the case of the POHSSCs, for dollar fluctuations.

TABLE 6-8. EQUIPMENT ACQUISITION COSTS*

Baseline	ITEM		ESTIMATED COST
ADAPTS	with one 2-stage pump		$ 70,000
OWOCS	boom with skimming weirs		110,000
Skimmer	pumps and raft		40,000
OWORS	skimmer		800,000
POHSSC	barges	Type O	236,000
		Type F	86,000
		Type D	36,000

*1976 dollars

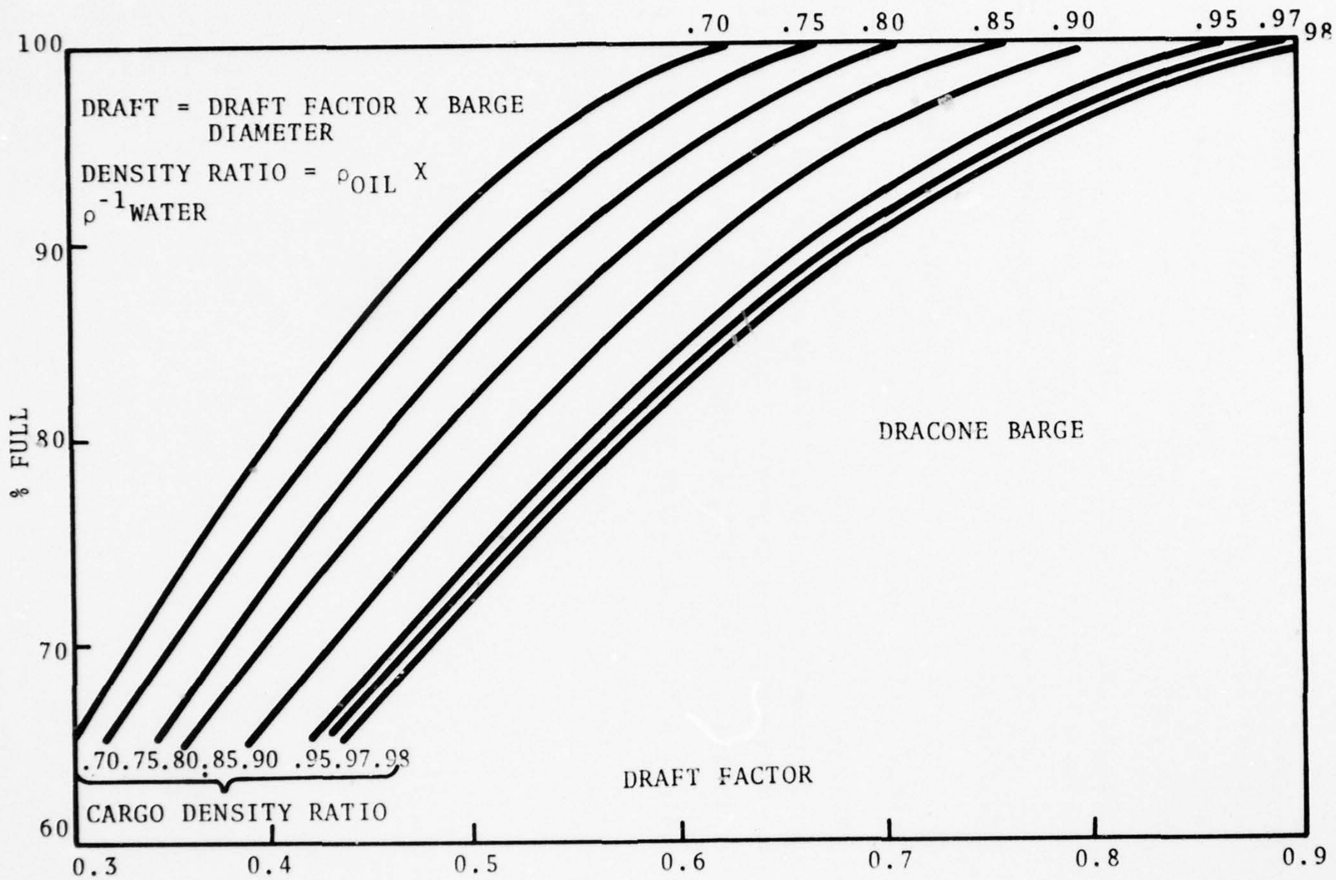


FIGURE 6-14. CURVES OF DRAFT FACTOR/% FULL FOR CARGO DENSITY RATIOS 0.70-0.98

AD-A070 815 TRANSPORTATION SYSTEMS CENTER CAMBRIDGE MA F/G 13/2
DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
FEB 79 J BELLANTONI, J GARLITZ, R KODIS
UNCLASSIFIED TSC-USCG-79-2-1 USCG-D-14-79-1 NL

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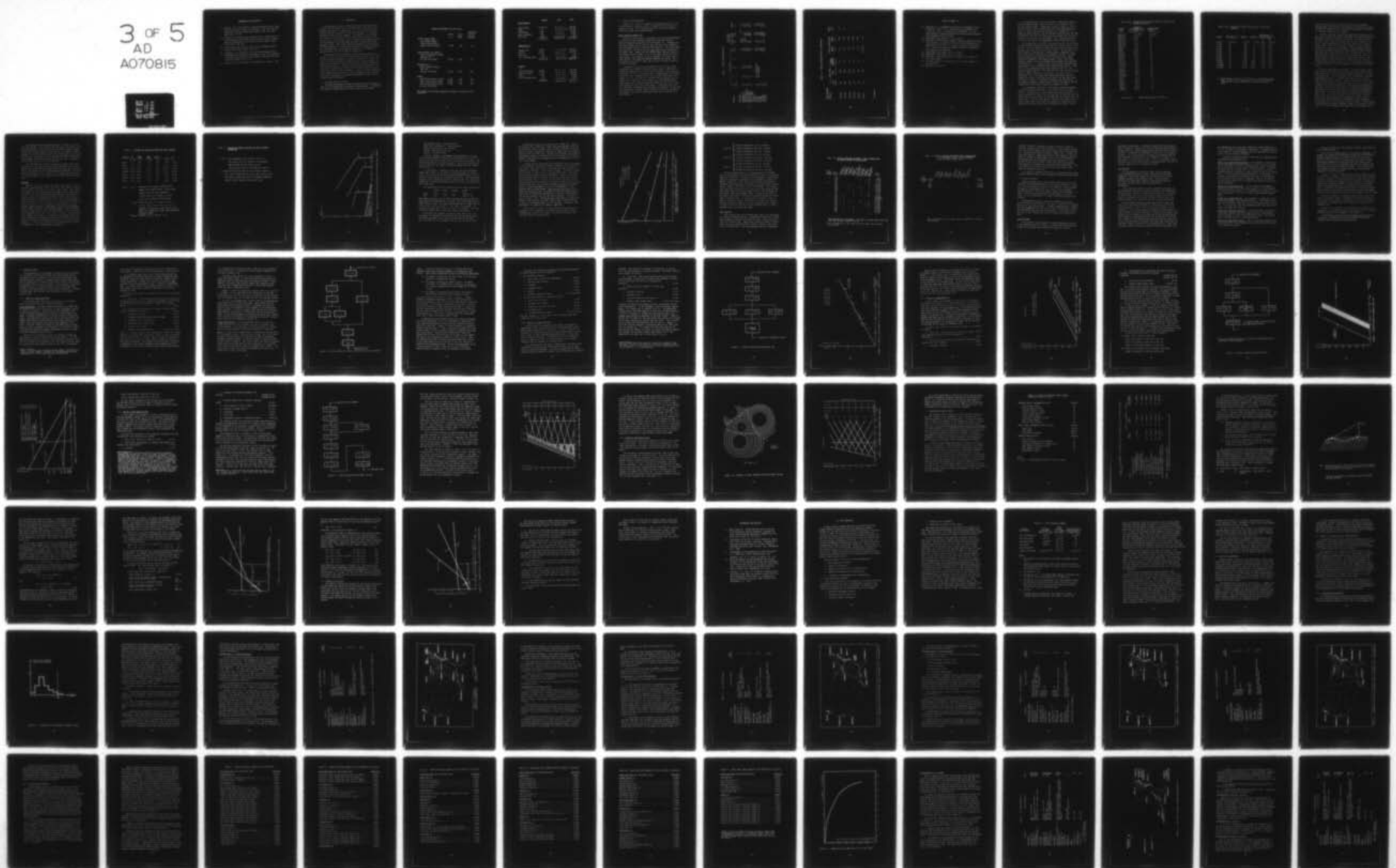
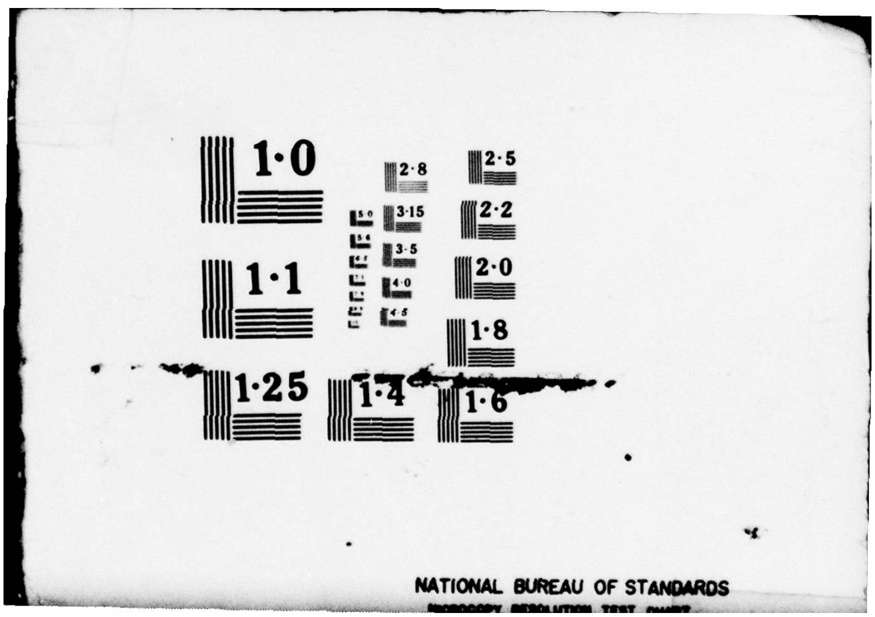



1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
1·1
4·5
1·8
1·25
1·4
1·6
NATIONAL BUREAU OF STANDARDS

REFERENCES FOR SECTION 6

6-1 Milgram, J.H., and Griffiths, "Combined Skimmer-Barrier High Seas Oil Recovery System," Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, Pub. No. 4284, March 1977, p. 375.

6-2 A Report on the Operational Capabilities of the Proposed Air Deliverable Anti-Pollution Transfer System, 3 Vols., Department of Transportation, United States Coast Guard, Plans Staff Office, May 1971.

6-3 Gulf Strike Team, National Strike Force, Equipment Manual, United States Coast Guard, July 1977.

6-4 Abrahams, R.N. and Miller, "Oil Spill Containment System Development and Testing," Proceedings of the Joint Conference on Prevention and Control of Oil Spills, American Petroleum Institute, March 1973, p. 361.

6-5 Leigh, J.T., "Oil Recovery on the High Seas," Ibid, p. 351.

7. LOGISTICS

The preceding sections of this report have investigated the potential for oil spills in U.S. coastal waters and some of the equipment available to combat them. In this section the various logistic options available to bring the equipment to a suitable debarkation point will be examined. The purpose is to estimate the range of each transport option within the specified 6- hour response time. These ranges, and corresponding equipment payloads, will be employed in the following sections to select sites and equipment levels. While the estimates developed in this section are aimed primarily at single-site response to non-massive spills, the information may also be applied to multi-site response to massive spills, as will be done in Section 10.

The procedure to be followed in this logistics study is as follows. First, the transport characteristics (weight, size, etc.) of the baseline equipment are assumed from Section 6. Next, the various vehicles that may be employed to carry the equipment are examined, in order to estimate their ranges, payloads, speeds and other characteristics. Finally, several logistic options (i.e., vehicles or combinations of vehicles) are selected and their payload-range characteristics developed. A review of these characteristics leads to the selection of three transport options (truck, air/truck, waterborne) for primary consideration in the site selection study of Section 8.

7.1 BASELINE RESPONSE SYSTEMS

The Baseline Response systems described in the preceding section will be assumed for the logistics investigation. In summary, the logistics characteristics of these units are as follows

BASELINE EQUIPMENT, PER UNIT DATA

	Pounds	Cubic Feet	Thousands 1976 US Dollars
ADAPTS Double Stage but without Single Stage Pump and Flow Meter, as per Table 6-1	6,000	200	60
OWOCS/Skimmer with Pumps & Float, Prime Mover, Hoses and Fuel Cell (as per list below)	19,000	1,100	175
OWORS/Barrier, Model 4000 with Hose & Fuel Cell (as per list below)	33,200	2,070	904
POHSSC			
Type OW with Pallet & Hose	13,700	738	240
Type F with Pallet & Hose	8,800	342	90
Type D with Pallet & Hose	3,800	270	40
(as per list below)			

The skimmers and storage equipment breakdown is given here for reference:

	Weight	Size	Cost
OWOCS/Skimmer			
Boom & Weirs	16,000 lbs	18 x 9 x 5	110,000
Pumps	700	5 x 9 x 3 1/2	40,000
Prime Mover	1,200	4 x 4 x 4	31,000
Hose, Connectors	600	3 x 3 x 6	3,600
Fuel Cell	460	2 x 3 x 2	200
	19,000 lbs	1100 Cu. Ft.	$175,000

	Weight	Size	Cost
OWORS/Barrier			
Skimmer 400	16,000	7 x 28 x 8.5	800,000
Barrier	16,000	18 x 9 x 5	100,000
Fuel Cell	460	2 x 3 x 2	200
600' Discharge Hose	720	3 x 3 x 6	3,600
	33,200 lbs	2070 Cu. Ft.	$904,000

	Weight	Size	Cost
POHSSC			
Type OW & Pallet	13,000	19 x 6 x 6	236,000
Type F & Pallet	8,064	12 x 6 x 4	86,000
Type D	3,052	9 x 6 x 4	36,000
600' Discharge Hose	720	3 x 3 x 6	3,600
	24,8361bs	1242 cu. ft.	$361,600

7.2 VEHICLE CHARACTERISTICS

Tables 7-1, 7-2 and 7-3 summarize the characteristics of the various possible transport devices considered for the baseline response systems. The assumptions and data that were employed to derive this table are discussed below.

Water Vehicles (Table 7-1)

The first five entries in the Table are based on data gathered by the Naval Coastal Systems Laboratory on the Fast Surface Delivery System (Planing Sled), FSD, Reference 7-1. Although the sled was designed for a 20,000 lb load, the tests were conducted with a maximum 17,000 lb load (the USCG Barrier). The lower figure was employed in the table because speed data are not available at the higher load. Ranges for the FSD/WPB-/WMEC-/UTB were based on the towing vehicle's range at the cruise speed, adjusted by the ratio $H_C/(H_C + H_T)$ where H_C is the horsepower for cruise under no load, and H_T is the added horsepower required for towing. This was taken as 313 hp at 17 knots and 221 hp at 12 knots, based on a 6000 lb tow force.

Subsequent to the tests of Reference 7-1, the Coast Guard reevaluated the FSD/HH3-F mode and found several circumstances mitigating against the use of the HH-3 helicopter, among them the following: (1) rise in transmission oil temperature, (2) possible stresses on the airframe, which would increase maintenance and reduce life, (3) the need for a retrofit for the towing rig, (4) surges in the tow line, (5) the need for a nose down attitude, which causes pilot discomfort and may reduce his ability to cope with emergencies, and (6) limited range. Considering these factors and other recommendations contained in Reference 7-3, the USCG has decided not to pursue further towing of the FSD by the HH3-F. Accordingly, this vehicle combination will not be considered in what follows.

TABLE 7-1 VESSEL CHARACTERISTICS

Vehicle	Max Load					Cruise at Max Load		
Vehicle	Wt	L	W	H	Area	Speed	Range	Draft
	10^3 lb	ft	ft	ft	ft^2	kts	n.mi.	ft
SLED/TOW								
FSD/HH3F[1]	17	27	9.0	-	243	46[2]	75[3]	1.5
FSD/RH53[1]	17	27	9.0	-	243	57[4]	-	1.5
FSD/82'WPB[1]	17	27	9.0	-	243	17[5]	419	6.0
FSD/210'WMEC[1]	17	27	9.0	-	243	17[5]	5800	10.0
FSD/41'UTB[8]	17	27	9.0	-	243	12	150	4.0
FSD/270'WMEC	17	27	9.0	-	243	19	4200	14.0
FSD/378'WHEC	17	27	9.0	-	243	28	2400	21.0
CUTTERS[6]								
52'MLB	10	LOAD DIMENSIONS			100	11	430	6.0
63'ANB	16	NOT STANDARD			375	15	210	4.5
82'WPB	6				200	24	470	6.0
95'WPB	8				400	20	440	6.0
210'WMEC	20				1500	16	6200	10.0
270'WMEC	60				2500	20	4130	14.0
378'WHEC	100				2500	16	10300	21.0

TABLE 7-1 VESSEL CHARACTERISTICS (CONTINUED)

BUOY TENDERS

Vehicle	Max Load			Cruise at Max Load		Draft
	Wt *	Area	Crane Capacity	Speed	Range	(ft)
	10^3 lbs	(sq. ft.)	10^3 lbs	kts	n.mi.	
180'WLB	200	1400	40	13.0	> 100	14
175'WLM	180	1200	40	12.0	> 100	12
157'WLM	130	1000	20	12.8	> 100	7
133'WLM	80	960	20	9.8	> 100	9
100'WLI	35	575	10	10.5	> 100	5
65'WLI	10	290	4	(7)(9.0 / 11.3)	> 50	4

*Estimated

NOTES TO TABLE 7-1

(1) Reference 7-1. Although the FSD sled was designed to carry 20,000 lbs. (Ref. 7-2, p. 418) tests were performed with 17,000 lbs or less, as described in Reference 7-1. The lower figure is used here because the speed and range figures were obtained using 17,000 lbs.

(2) Significant wave height 1.5 ft. in tests.

(3) Estimate via USCG Aviation Branch, Search and Rescue Division. This estimate is based on 3,000 lbs of fuel employed in the Panama City tests, Ref. 7-1, and in the tests of Reference 7-3. Further investigation would be needed to determine if this range can be increased.

(4) Significant wave height 2.0 ft. in tests.

(5) Significant wave height 1.0 ft. in tests.

(6) Reference: Publication USCG-197, "Register of Cutters of U.S. Coast Guard."

(7) 9.0 knots applies to the 303 class; 11.3 knots applies to the 400 class.

(8) Reference 7-1, pE-24.

The characteristics of the two vehicle combinations FSD/270' WMEC and FSD/378' WHEC, shown in Table 7-1, are based on tests with the FSD/210' WMEC. Although no reports of specific tests of the FSD towed by cutters larger than 210' were found during the study, it seems that no major problems can be identified. It should be noted, however, that the 28 knot speed with the 378' WHEC would differ from the same speed condition achieved by helicopter primarily in the lower tow line angle. This lower angle may increase the possibility of submerging the bow in high sea states.

The elimination of the HH3-F helicopter tow for the FSD brings up the question of availability and ability of USCG vessels to tow the FSD. Only the WPB/82 and WMEC/210 were tested at Panama City, although some runs were made with the UTB/41. The availability of USCG vessels for towing duty is investigated in Appendix H and the results will be discussed in subsequent sections. Possible FSD tow speeds were estimated for the 20 cutters/and 6 boats selected in Appendix H are shown in Table 7-2(a). The towing speeds in Table 7-2(a) for the WMEC/210 and WPB/82 were obtained from Reference 7-3. Towing the FSD, these vessels achieved planing speeds, as did the UTB/41 which develops only 640 h.p. Therefore, it was assumed that any vessel with over 640 h.p. can achieve planing speed at 17-21 knots (p E-11, E-12, E-13) with the OWOCS or OWORS, provided its top speed is 17 knots or more (Reference 7-3). The large buoy tenders and harbor tugs were assumed to be able to tow the sled at their own top speed, generally about 10 knots. The MLB/44 and MLB/54 have only 400 hp installed and probably cannot reach 10 knots, the hump in the FSD towing force curve; hence 5 knots was assumed for them.

It is apparent from Table 7-2(a) that the FSD was designed for planing speeds, achievable by the WPB/82 and other large cutters. The majority of the eligible towing fleet, however, lie below the WPB/82 in Table 7-2(a) and (except for the UTB) have top speeds that put them closer to the hump than the trough of the tow-force curve. This may even apply to the UTB, since Reference 7-3 merely states that the UTB/41 "was capable of towing the configuration to planing speeds and of maintaining 12 knots," which

TABLE 7-2(a) ESTIMATED AVERAGE TOWING SPEEDS, SELECTED USCG VESSELS TOWING FSD

VESSEL TYPE	UNDERWAY AND STANDBY HOURS IN 1975	TOWING SPEED KTS(1)
WHEC/327	18.7×10^3	20 knots
WHEC/378	51.3	20
WMEC/210	100.3	17
WMEC/213	6.7	17
WMEC/205	15.0	17
WMEC/143	13.0	17
WMEC/-	6.0	17
WPB/95	148.2	17
WPB/82	362.3	17
WLB/180	201.3	13
WLM/177	25.0	12
WLM/157	46.5	12
WLM/133	41.0	9
WLI/100	14.9	10
WLI/100	14.3	10
WLI/65	42.4	10
WYTM/110	80.8	10
WYTL/65	103.8	10
WYTM/UNK	8.7	10
BU/40	11.0	5
BU/45	142.2	5
MLB/44	870.9	5
MLB/52	37.2	5
UTB/40	1147.9	17
OTH/>40	513.5	10

(1) See text Mean towing speed 12.16 knots

TABLE 7-2(b) APPROXIMATE TOWING CAPABILITIES OF SOME USCG CUTTERS

CUTTER	MAX SPEED, V_m	MAX HP	DISPL, Δ	APPROXIMATE MAX TOW SPEED(1)	
				(a)	(b)
26'MRB	25 knots	300 HP	4 tons	kts	14.8 kts
32'PWB	25	390	9	15.3	18.0
41'UTB	26	640	15	18.0	20.6
44'MLB	14	400	19	10.2	11.5
52'MLB	11	400	35	8.9	9.8
55'ANB	22	1,090	34	17.8	19.4
63'ANB	15	800	42	12.5	13.5
82'WPB	24	1,600	67	21.2	22.4
95'WPB	20	2,324	100	18.3	19.0
210'WMEC	16	5,000	1,000	15.8	15.9
270'WMEC	20	7,000	1,730	19.9	19.9
378'WMEC	28	36,000	3,000	27.9	27.9

(1) Approximated as $V_m(\Delta/(\Delta_L+\Delta))^{1/3}$ where Δ_L, the load displacement, is (a) 30 tons, (b) 15 tons. It is assumed that the towed vessel is not a planing hull and that the water is calm.

leaves open the question of whether the UTB/41 can maintain planing speeds while towing. The question is significant because the UTB/40 is about 29% of the eligible towing fleet on the basis of 1975 hours underway or on standby.

The FSD is not the only vehicle capable of carrying the largest piece of pollution response equipment (Open Water Barrier and Container, 17,000 lbs) behind a USCG cutter. To allow for the possibility that other non-planing vessels may be employed, theoretical towing capabilities of some USCG cutters are listed in Table 7-2(b). This table is based on towing a vessel of either 60,000 lbs or 30,000 lbs displacement. The assumptions made in deriving the maximum theoretical towing speed are that the horsepower required to move either vessel is proportional to its displacement and to the cube of its speed, and that the total horsepower required is applied entirely by the towing vessel. The design speeds of both vessels were assumed equal for simplicity. Average practical towing speeds will vary according to the design of the two vehicles, and will probably be less than shown in the table.

The next seven vehicles in Table 7-1 are USCG cutters alone. Almost every cutter has some deck space and cargo capacity that may be employed to carry pollution response equipment. The major limitations are: (a) cargo capacity, (b) availability of loading and unloading devices, (c) usable deck area and (d) sea state limits of the smaller vessels. Table 7-1 lists USCG cutters with load carrying capacity of 6,000 lbs or more. All of these require a crane or lift or equivalent device for loading and unloading. Therefore, they may be considered for transporting equipment only between ports that have such devices, and which can accommodate their draft. There are approximately 150 potential debarkation ports in the U.S. (Atlantic Coast, Gulf Coast, Pacific Coast, Great Lakes, Puerto Rico) that have cranes or lifts. They are listed, with draft information in Appendix E. The effective cruise range for the seven cutters listed in Table 7-1 was obtained by multiplying the normal (unloaded) range of the vessel by D/(D+L) where D is vessel unloaded displacement and L is equipment load.

The final group of waterborne vehicles in Table 7-1 is the USCG Buoy Tenders. All of these vehicles carry a boom that can be used at most ports as well as at sea. The restrictions on boom use are the lifting capacity of the boom (i.e., heaviest single package it can lift) and the height from tender deck to dock level at low tide. In some ports (e.g., Boston, Portland) the 180' WLB crane cannot load off or onto the dock at low tide. A complete list of such restrictions is not available.

The 180' WLB and 175' WLM can operate at almost full effectiveness in 6'-10' seas; the 157' WLM can probably do so in 2'-3' seas; the 133' WLM and the inland tenders WLI are usually restricted to seas below 2'-3' for load and unload operations. As in the case of the other cutters, range is not a significant restriction for the buoy tenders in the delivery of pollution response equipment.

Aircraft

Table 7-3 shows the payload and range characteristics for six aircraft types presently used by the USCG. This table is calculated from data on maximum gross weight, empty weight, fuel capacity, crew number, cruise speed and fuel consumption rates provided by the USCG. The resulting payload-range relations are plotted in Figure 7-1(a). The assumption behind the Table and the Figure is that payload may be traded off for fuel, with a corresponding increase in range, within the limits set by maximum gross weight and fuel tank capacity. This assumption is not accurate, and the results, shown in Table 7-3 and Figure 7-1(a) can be considered only a rough estimate of load carrying capacity. These estimates must be refined, in the case of the helicopters, for the maximum hovering weight limit, and in the case of the C130, for wing fuel/gross weight restrictions. In addition, the unloaded weight can vary substantially depending on the Search and Rescue mission for which the aircraft was configured prior to its use for pollution response. A more accurate analysis of the HH3 and C130 is given in Appendix F. The configurations covered are:

TABLE 7-3 **PAYLOAD AND RANGE RELATIONS FOR USCG AIRCRAFT**

Vehicle	P_o 10^3 lbs	R_{max} n.mi.	P_{max} 10^3 lbs	Speed V kts	f lbs/hr	C_T lbs
HH52A	1.5	300	0.0	80	409	2,112
HH3F	6.3	660	0.0	126	1,200	7,200
HC130B	58.6	3,250	13.3	290	4,030	45,240
HC130H	87.9	3,850	25.0	300	4,900	62,920
HU16E	8.5	2,054	0.0	145	600	10,000
HC131A	34.9	1,580	25.6	170	990	9,180
HU25A	10.2	2,200	0.3	405	1,820	9,910

NOTES: (1) p_o = Payload at zero range = Maximum gross weight minus (empty weight + crew weight weight at 200 lbs per crewmember + reserve fuel for 45 minutes if fixed wing, for 20 minutes if helicopter)

(2) R_{max} = Range when fuel is limited by either (a) payload, when used to carry fuel, or (b) capacity of fuel tank, = min $(VP_o/f, VC_T/f)$, where C_T is capacity of fuel tank (excluding auxiliary tanks)

(3) P_{max} = payload at R_{max} = max $(0, P_o - C_T)$

TABLE 7-3 **PAYLOAD AND RANGE RELATIONS FOR USCG AIRCRAFT (CONCLUDED)**

(4) f = fuel consumption rate based on use of a JP4 weight fuel (6.5 lbs/gal) for the HH52A, HH3F, HC130B, HC130H, HU25A, and of 115/145 weight fuel for the HU16E and HC131A.

(5) Data for max gross weight, empty weight, number in crew, fuel consumption rate, fuel tank capacity, and fuel density taken from table of AIRCRAFT CHARACTERISTICS, 8/28/77 obtained from USCG/G-OSR-2.

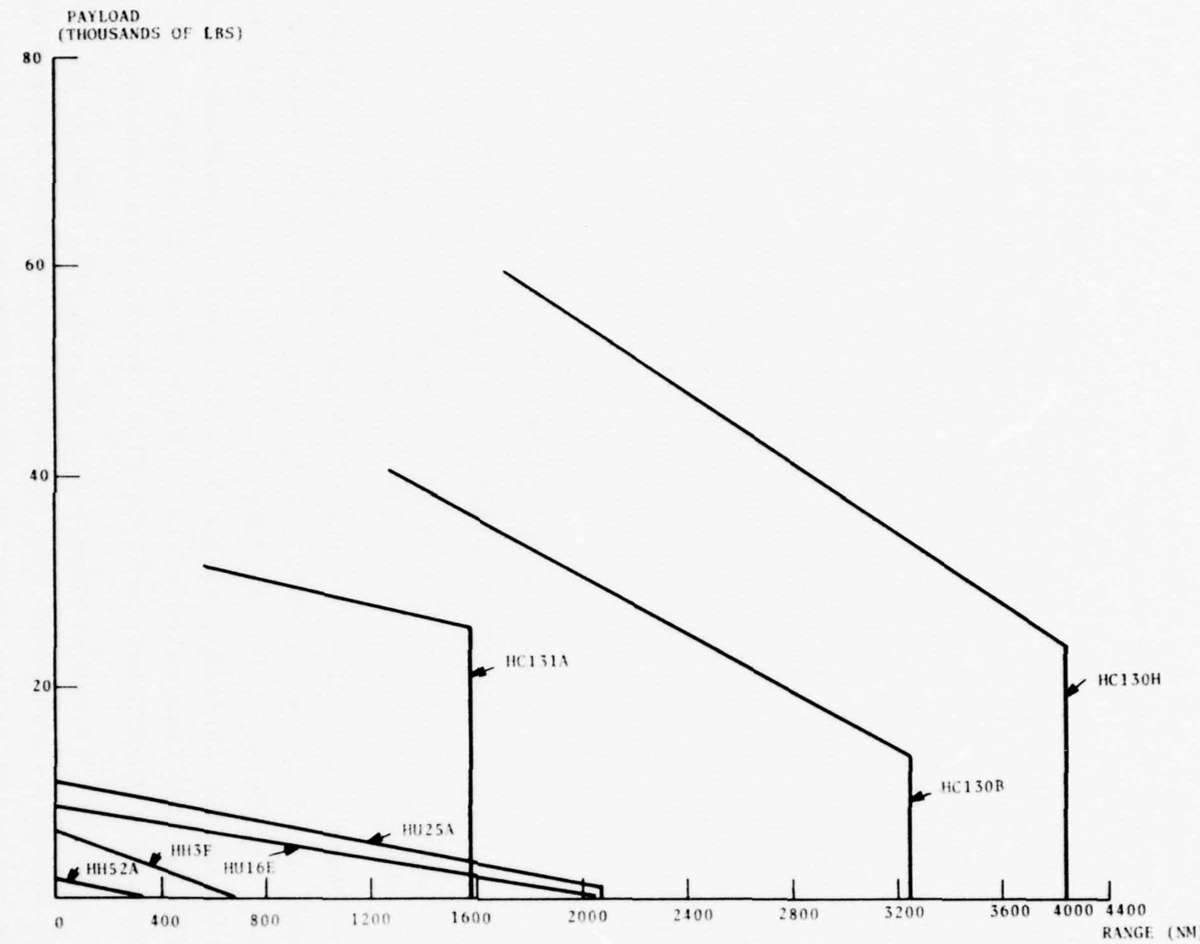


FIGURE 7-1(a) APPROXIMATE RANGE-PAYLOAD CHARACTERISTICS OF CURRENT USCG AIRCRAFT

HH3 internal cargo - one-way mission,
HH3F belly slung cargo - two-way mission,
HH3F internal cargo - two- mission,
HC130B - one-way mission, and
HC130H - one-way mission.

From this Appendix (see Figures F-1, and Table F-1) it can be seen that the HH3F is limited to about 5800 lbs on a 50 n. mi. one-way mission and to about 2600 lbs on a 400 n.mi. mission. The belly-sling mode has the same payload as the internal mode on two-way missions, but its range is limited to about 150 n.mi. rather than 200 n.mi.

For the HC130, it should be noted that the payload depends, among other things, on the empty or operating weight of the aircraft. This can vary with the interior equipment chosen; the life raft may be eliminated for overland flights, etc. USCG experience suggests a basic operating weight of about 90,000 lbs, which gives the HC130H a payload of 40,000 lbs over 1,000 n.mi. and 22,000 lbs over 3,400 n.mi.

The approximate interior dimensions of the HC130 and HH3F are:

	LENGTH	WIDTH	HEIGHT	VOLUME
HC130	39'6"	10'3"	9'1"	3678 cu. ft.
HH3F	21'2"	6'4"	6'3"	838 cu. ft.

The length given here for the HC130 interior does not include the ramp, which is approximately 8 ft. long. The HC130 interior can hold 4 pallets, each 7'4" long, plus one pallet 4'6" long, each the width of the interior, with a 5' x 10' area for personnel. In addition the ramp, when closed, can hold a 7'4" pallet. The HC130 can hold 4 ADAPTS pump systems plus several team members.

The HC130B can transport one barrier over 1000 n. mi., but the amount of equipment over and above the barrier depends upon the operating weight (gross weight without fuel and payload). If this is 80,000 lbs, as is common, then very little can be added.

The HC130H can carry two barriers over a 1000 n.mi. range, or one barrier over a 3400 n.mi. range, with approximately 5,000 lbs of additional cargo, assuming a gross weight of 90,000 lbs without fuel or payload. Additional cargo can be added when the required range is less than 3400 n.mi. Because the dimensions and weight of the skimmer, barges, and ADAPTS are less than those of the barrier, numerous combinations of equipment can be accommodated if the barrier is not loaded.

Aircraft not in the present USCG inventories are also relevant to air transport of pollution response equipment in the 1980-1990 time frame. These may either be borrowed from other services, or purchased by the USCG. In the latter category, it should be noted that the HH3F is expected to be replaced about 1980. The task of transporting pollution response equipment is likely to fall upon the replacement vehicle at least to the same extent that it has fallen upon the HH3F. In order to assess the impact of these future helicopters on the pollution response mission (and vice-versa) several heavy duty U.S. military helicopters currently in production or in late development, are listed in Appendix G. This Appendix shows the approximate range-payload characteristics of five such helicopters,(not including the HH3F and variants of it). While some of these offer payloads well in excess of the HH3F's, the one-way distances are not necessarily greater. This can be seen in Figure 7-1(b), showing payload-range points for the CH-47C Chinook, S-64 Skycrane, CH-53A/2-Turbine, and CH-53E/3-Turbine, as well as the payload-range line for the HH3F. Obviously, more information is needed for a complete comparison.

Since specific vehicles for the 1980-1990 period cannot be designated, it is necessary to consider several generic types, including one similar to the HH3F, for pollution response work. The three classes considered are:

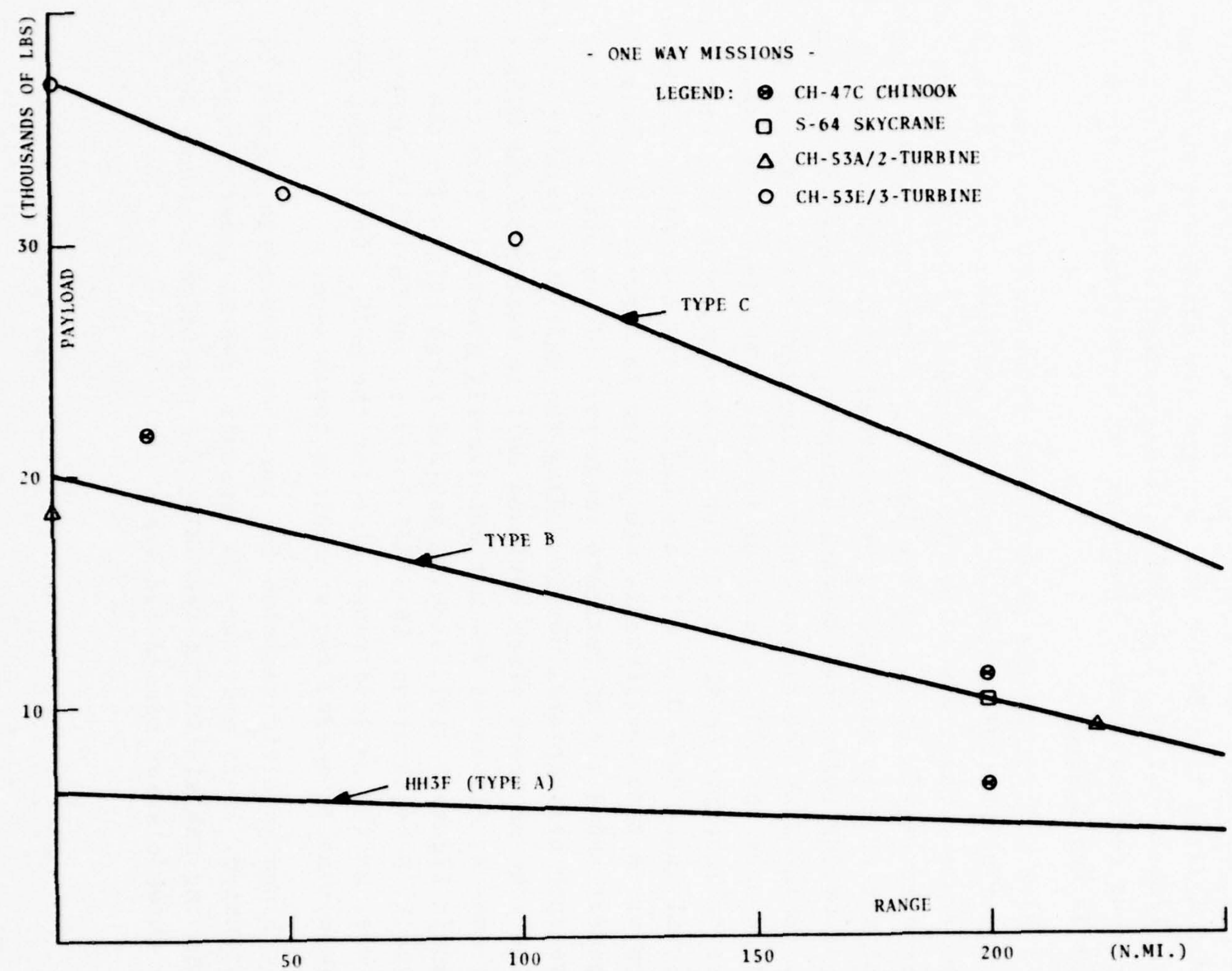


FIGURE 7-1(b) APPROXIMATE RANGE-PAYLOAD CHARACTERISTICS OF CURRENT U.S. MILITARY HELICOPTERS

Class A:	6,350 lb payload at 0 n.mi., one-way 5,000 lb payload at 200 n.mi., one-way 6,000 lb payload at 100 n.mi., two-way
Class B:	20,000 lb payload at 0 n.mi., one-way 10,000 lb payload at 200 n.mi., one-way 12,000 lb payload at 100 n.mi., two-way
Class C:	37,000 lb payload at 0 n.mi., one-way 20,000 lb payload at 200 n.mi., one-way 24,000 lb payload at 100 n.mi., two-way.

The first group, Class A, is characteristic of the HH3F; Class B is typical of the CH-47C and CH-53A; Class C is representative of the CH-53E. The ability of helicopters in these three classes to transport the baseline system elements is given in Tables 7-4 and 7-5. These tables give several combinations of equipment and men that can be carried on a single one-way trip of various ranges by the three classes of helicopter. The combinations have been selected so as to stay within the volume and payload capabilities of the helicopters (with a 1,000 lb margin on the weights taken from Figure 7-1(b)). Except for the Class C helicopter, the range is limited by helicopter capability rather than by response time. It will be seen in Section 7.4 and in Figure 7-6 that the Class C helicopter, on a 300 n.mi. mission, would be limited in range by the 6-hour response time. Hence it is shown in Table 7-4 for the 12-hour response time (or 6-hour response with a 30-minute load time).

Land Vehicles

Land transport may be by conventional truck or by any number of specially designed vehicles. Conventional trucks may be Coast Guard equipment, borrowed from other services, rented, or drawn from the GSA motor pool. Conventional tractor-trailers are available with gross combined weights (tractor, trailer, load, fuel, driver) of 80,000 lbs. The corresponding load may be estimated

TABLE 7-4 **TYPICAL BASELINE EQUIPMENT - RANGE COMBINATIONS FOR THREE CLASSES OF HELICOPTERS**

HELI-COPTER CLASS	RANGE (n.mi.)	Barrier 17,000 lbs	OW Barge 13,000 lbs	F Barge 8,000 lbs	ADAPTS 5,500 lbs	1/2 ADAPTS* 3,000 lbs	D10 Barge 3,000 lbs	Skimmer 3,000 lbs	Team Member 200 lbs	TOTAL (lbs)
A	200					1			5	4,000
	200						1		5	4,000
	200							1	5	4,000
B	100		1						5	14,000
	100			1	1				2	13,900
	100			1		1	1			14,000
	100			1			2			14,000
	100				2		1			14,000
	200			1					5	9,000
	200				1		1		2	8,900
C	100	1					1	1	10	25,000
	100		1		2				5	25,000
	100		2							**26,000****
	100	1		1						25,000
	100		1		1		1	1	2	24,900
	100		1	1			1		5	25,000
	200	1							10	19,000
	200		1					2		19,000
	200				3				12	18,900
	200			1	2					19,000
	200		1				2			19,000
	200		1		1				2	18,900

***Any combination of equipment from Table 6-1 that totals less than 3000 lbs and less than 120 cu. ft.**

**This combination is less than 1,000 lbs under the estimated max payload.

TABLE 7-5 **TYPICAL BASELINE EQUIPMENT-RANGE COMBINATIONS**
- 12-HR RESPONSE TIME, OR 6-HR RESPONSE WITH 30-MINUTE LOADING TIME-

HELI-COPTER CLASS	RANGE n.mi.	Barrier 17,000	OW Barge 13,000	F Barge 8,000	ADAPTS 5,500	1/2 ADAPTS 3,000	D10 Barge 3,000	Skimmer 3,000	Team Member 200	TOTAL (lbs)
C	300		1							13,000
	300				2				10	13,000
	300			1	1					13,500*

*This combination is less than 1,000 lbs under the estimated max payload.

at about 50,000 lbs (allowing a 15,000 lb tractor, 12,000 lb trailer). Widths are limited to about 8 ft; semi-trailer lengths up to 40 feet are common, and longer lengths can be obtained readily. Platform semi-trailers can be as high as 54". In order to clear the usual 14' underpasses found on most highways, the cargo height is limited to approximately 9 ft, with 8 ft preferable. Non-conventional flat bed semitrailers are available to carry 10,000 lbs per foot of length. Drop frame flats are available with capacities of 80,000 lbs with evenly distributed loads. Special permits are required for excessively wide, long or heavy loads, according to state laws.

As a point of reference for costs, it is noted that an 80,000 lb gross combined weight tractor retailed for about $50,000 in 1976.

7.3 LOGISTIC OPTIONS

Having reviewed some of the relevant characteristics of the equipment to be transported and of the vehicles available to carry it, it is now possible to describe very generally several schemes for getting the equipment from its site(s) to the designated debarkation point. Only five general schemes are considered. In fact, it will be shown that only five are likely to be of any value. A brief discussion is in order of how these schemes were selected.

The debarkation point is necessarily dockside at a port, which dockside is accessible by sea, land, or (possibly) helicopter but not by fixed wing aircraft. (Except in unusual cases, airports that can accomodate C130 size aircraft are not adjacent to a dock; an intermediate land leg would be required). At the other end of the trip is the storage site, which is either on a vessel or on land.

Vessel Storage

If on a vessel, the equipment is either transported directly to the debarkation point by water, or removed from the vessel and brought there through some intermediary vehicle(s) (truck,

helicopter, fixed wing). The latter case occurs when the equipment is stored on a vessel in a port of high spill potential, and a spill occurs at a great enough distance from the port to make it necessary to transport the equipment by land or by air instead of by water. It is then necessary to remove the equipment from the water (perhaps with the vessel) and transport it by land or by helicopter to the debarkation point, or to an intermediate airport. The time lost in the transfer must be balanced against the cost of storing a duplicate set of equipment on land.

Land Storage

If the equipment is stored on land, it may be brought to the debarkation point by either single-mode or dual-mode transport. Three-mode schemes may be ruled out for six-hour response because of the interface times. The only possibilities for single-mode transport originating on land are (a) truck, (b) helicopter, both of which will be considered.

Of the two-mode schemes, one may eliminate truck/water and helicopter/water because waterborne transport to the debarkation point cannot be superior to truck when an interface is required. In other words, since truck speeds almost always exceed water speeds, truck/water will usually be inferior to all truck, and helicopter/water will usually be inferior to helicopter/truck.

The only other two-mode possibilities are (a) fixed wing/truck, (b) fixed wing/helicopter, (c) helicopter/truck and (d) truck/helicopter. The last two are limited in capacity by the helicopter. If the time required to transfer from helicopter to truck is equal to the time required to refuel the helicopter, then nothing would be gained by the truck leg in the helicopter/truck option unless the debarkation point were inaccessible by helicopter. Similarly, the truck/helicopter option would be inferior to a multi-leg helicopter trip unless there were some reason that the helicopter could not operate from the equipment site. Both situations are unlikely because the storage sites are selectable, and

the debarkation point dock would probably be large enough (70' by 70' for the HH3F) to accommodate a helicopter. Although these two cases cannot be excluded a priori, they are considered too specialized to justify extensive treatment.

A review of the above analysis shows that the schemes warranting detailed consideration are:

Option (1), Single-Mode Waterborne: The equipment is stored on a vessel dedicated to pollution response, (e.g., the FSD or similar vessel) and towed or sailed to the debarkation point. This mode has merit when the storage vessel is itself moored at a major debarkation point, allowing it to go directly to the spill in many cases. It has a notable disadvantage when it is necessary to transfer the equipment (and perhaps the vessel) to land whereon one of the next four options is employed. The two versions of the water borne option will be termed Direct Waterborne and Transferred Waterborne.

Option (2), Single-Mode Land: In this scheme the equipment is taken overland by truck from a land storage site to the debarkation point dockside, where it is unloaded (and re-loaded for transport to the spill, if the spill is not at the debarkation point dock).

Option (3), Single-Mode Air: The equipment is picked up by helicopter and brought to the debarkation point. The storage site in this case would most likely be at a USCG helicopter base, or near one. It is necessary that the debarkation point have facility to land a helicopter and refuel it.

Option (4), Dual-Mode Air/Land: As discussed above, this must be fixed-wing transport from the storage site to an intermediate field, and then by truck to the debarkation point. The storage site is assumed to be at a fixed wing airport.

Option (5), Dual-Mode Air/Air: This is fixed wing transport from the storage site to an intermediate field, and then by helicopter to the debarkation point.

Before discussing the above logistic options, some qualifications should be noted.

First, not all schemes apply to all pieces of equipment. For example, the current USCG helicopters cannot lift the CG barrier. Dedicated skimmers must be stored on or near the water-borne vehicle, while the ADAPTS and other pumps would present severe maintenance problems if stored aboard any but a large vessel. Also, local facilities and geography may make some options more attractive at one location than at another. It is possible that some equipment should be transported by one method and other equipment by some other method.

Second, it should be emphasized that these options all refer to delivery of equipment to the debarkation point, rather than to the spill location. By debarkation point is meant the waterside location from which the equipment may be loaded or launched for delivery to the spill location. Except for Option 1, unloading time at the debarkation point is not inlcuded in the response time. In Option 2, the equipment site may be a garage or storage area close to the pierside or launch ramp, but still far enough away to require a delivery device such as a loader, truck, or crane.

Third, the quantity of equipment required will affect the choice of delivery option. The number of aircraft available in the present USCG inventory, in particular, is such as to restrict the amount of equipment that can be delivered in the specified response time.

Finally, the transport of the response team itself must be considered. It is desirable, but not essential, that the response personnel move with the equipment if not before it.

The following sections give the assumptions and approximations made in estimating the relation between distance and response time for each of the above options.

7.4 RESPONSE RANGES

The purpose here is to estimate, for each of the five options just described, the maximum distance that the equipment may be transported from its storage site in the specified response time. Considerations of quantity of equipment and existing capabilities will be introduced in Sections 8 and 9, where actual site locations and equipment levels will be discussed. In the present section the maximum distances, or response ranges, will be calculated from assumptions and approximations on the speeds, availability, loading time and other time intervals that contribute to the overall response time.

7.4.1 Option 1, Single-Mode Water

As discussed above there are two versions of this option, namely Direct Waterborne and Transfer Waterborne.

Direct Waterborne: The OWOCS, POHSSC and possibly the OWORS* may be stored on the FSD or similar boat for rapid deployment in areas of high spill potential. The FSD can be semi-submerged at the spill site thereby obviating the need for a crane to deploy its cargo. Although the ADAPTS may be carried as easily as the other pieces, the submersible feature of the FSD is not required for the ADAPTS, which must be hoisted aboard the stricken vessel by helicopter or by conventional vessel rather than deployed in the water. Moreover, indefinite storage of the ADAPTS and its prime mover in a hull as exposed to the elements as the FSD will certainly increase the ADAPTS maintenance requirements, and at the same time make maintenance more difficult.

The use of a self-powered vessel for equipment storage and deployment will not be considered for several reasons: (1) adequate towing vessels are usually readily available in harbors where the FSD is likely to be stationed, (2) a self-powered vehicle would be substantially more expensive than the FSD, (3) a self-powered

*OWOCS - Open Water Oil Containment System, OWORS - Open Water Oil Recovery System, POHSSC - Portable Oil and Hazaradous Substance Container, FSD - Fast Surface Delivery (Planing Sled)

vessel with the submersible feature of the FSD is a difficult design problem. (Reason (1) will be substantiated in what follows.)

It is assumed, then, that in the Direct Waterborne option, the equipment is stored on FSD sleds or similar submersible planing hulls, which are either moored or stored on a launch ramp at a USCG installation. Storage in a shed or on the dock is not covered in the following analysis, but is treated as Single-Mode Land. It is also assumed that equipment stored on a vessel is in a functioning, ready-to-go condition, equivalent to what can be achieved on shore.

The major time intervals associated with the Direct Waterborne option are:

a. Alert time: Time elapsed during receipt and recording of OSC message, notification of response team commander, notification of other base officers and issuance of request for a towing vessel . . . . 15 min

b. Notification and assembly of response team personnel, initial assignments to officers . . . . 45 min

c. Personnel briefing. . . . . 15 min

d. Equipment check and launch (sled on ramp) . . . . 25 min

e. Equipment check (sled afloat) . . . . 30 min

f. Availability of towing vessel . . . . 60 min

g. Securing of tow line. . . . . 5 min

h. Response Range R/Mean Speed . . . . . R n.mi./12.2 knots

Item f. is a highly variable time, depending on whether the storage vessel is at a large USCG installation or not, as well as upon the District in which it is located. The value shown is typical for most Districts in the U.S., except Hawaii, Alaska and District 2, which has no seacoast. The estimate for each District is derived in Appendix H. The curves developed in that Appendix give the probability of one or more suitable towing vessels being available

at a storage vessel location in time t hours or less, for each of the nine Districts. A probability level of 95% is employed for estimation purposes here.

The mean towing speed of 12.2 knots employed in item h. is taken from Table 7-2(a). If only high speed towing vessels are employed, then the mean speed may be increased to about 17 knots. However, the use of these vessels reduces the available vessel time from 4023 thousand hours per year to about 1869 thousand hours per year, a reduction of 54%.

Figure 7-2 shows the sequential-parallel flow of the intervals a. through h. It is seen that vessel availability at the 95%. level takes less time than the parallel operations of (b) assembly-ing the response team, (c) briefing, and (e), (d) equipment checks.

At time T the equipment has arrived either at the debarkation point water area or at the spill scene. This differs from the other options to be treated in which T represents the time for delivery (but not unloading) of the equipment to the debarkation point landside. In order to compare these options with the Direct Waterborne an interval must be subtracted from Direct Waterborne times to allow for unloading at the debarkation point dock, loading onto a vessel or helicopter, and travelling to the spill location. These times will be estimated in Section 7.5.

Transfer Waterborne: If the debarkation point is located far enough away from the water storage site, and if alternate land-based equipment is not available, it may be necessary to transfer the water-based equipment to land and transport it from there.

Case 1. If the FSD or storage vessel is moored away from the dock it is necessary to tow it into the dock or ramp. Due to the short distance involved almost any auxiliary vessel may be employed, assuming favorable weather. In adverse weather a harbor tug WYTM or WYTL would be required. Once at the shore, the sled and contents would have to be hauled onto the dock (requiring a 15-ton crane) or up a ramp (also requires power, but probably not a crane). Once on the dock or ramp, the vessel and equipment would have to be loaded onto a truck or helicopter.

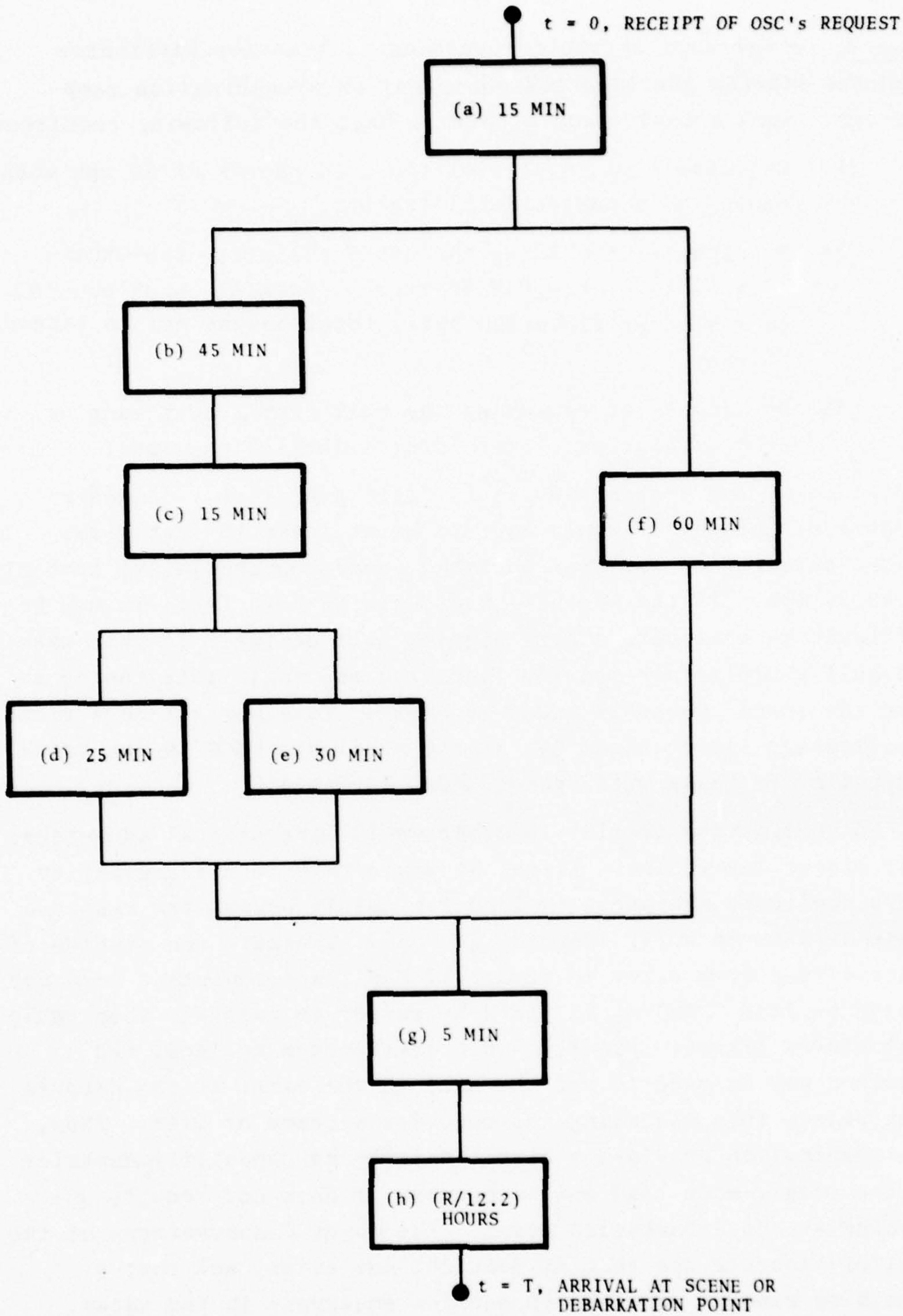


FIGURE 7-2 TIMING DIAGRAM FOR SINGLE-MODE WATER (DIRECT WATERBORNE)

Case 2. A far more attractive version of Transfer Waterborne requires storing the sled and equipment on a combination ramp-trailer. Such a device would have to meet the following requirements:

(1) Be capable of legal over-the-road speeds of 50 mph when hauled by a conventional tractor.

(2) Be capable of holding the OWOCS (9x5x12), the OWORS (7x8.5x28) or the POHSSC type F (6x4x13), each mounted on a sled or flotation hull, total height not to exceed 14 feet.

(3) Be capable of launching the hull from a boat ramp or dock without assistance from a derrick or crane.

The width of the present FSD is 15 feet; a trailer - launcher capable of holding it would have to be at least 15 feet wide, which would reduce its over-the-road speed substantially, probably to 10-20 mph. If the width is kept down to 9-10 feet, it may be difficult to achieve a stable planing hull design. In that case, the hull would merely provide flotation and facilitate towing at some low speed, probably under 10 knots. This may not be a great disadvantage since about 54% of the available USCG towing boat-hours lies in boats with speeds under 13 knots.

A combination trailer-launcher would have several advantages over Direct Waterborne. First, it would make it unnecessary to store duplicate equipment on land for spills beyond the response range of a towed hull. Second, it would eliminate the problem of transferring from water to truck, if duplicate equipment were not stored on land. Third, it would be easier to maintain than equipment stored afloat. Finally, when transported by land, the launcher may be used to put the hull in the water at the debarkation point, thus obviating the need for a crane or lift. Thus, the combination provides a Direct Waterborne capability superior to the single-mode land option because it does not require unloading at the debarkation point. The major disadvantages of the trailer-launcher are that it does not now exist, and that a launching ramp is required to put the equipment in the water.

The major time intervals associated with Transfer Waterborne by trailer-launcher are all sequential:

1. For waterbased response:

   a. Alert time, as for Direct Waterborne. . . . . 15 min

   b. Response Team assembly. . . . . 45 min

   c. Briefing. . . . . 15 min

   d. Equipment check . . . . 20 min

   e. Launch. . . . . 10 min

   f. Response Range/Mean Speed . . . . R n.mi/10 knots

2. For over-land response to debarkation point,

   a. Alert time, as above. . . . . 15 min

   b. Response Team assembly. . . . . 45 min

   c. Briefing of response personnel. . . . . 15 min

   d. Equipment check . . . . 20 min

   e. Overland Range/Mean Speed . . . . R n.mi/33.3 knots

The time interval e, is the same as that for Single Mode Land (truck) to be discussed next.

7.4.2 Option 2, Single-Mode Land

In this option, the equipment and, perhaps, personnel are loaded into a motor vehicle(s), driven to the debarkation point, and unloaded at dockside or launch site. If the storage site is located at the debarkation point, the motor vehicle may be a fork lift, crane, or other loading/transporting device. These cases will be treated separately. The primary case to be examined is that of transport by truck, or tractor-trailer over a greater distance than the diameter of a military base.

The time intervals and speeds assumed below are based on USCG experience, discussions with Strike Team officers, and in some cases on subjective judgment. It will be assumed that all equipment has been pre-loaded on flat-bed trailers dedicated to pollution

response. The tractors are assumed to be assigned to the base site, but not dedicated to pollution response. The major intervals are estimated as follows:

a. Alert time: Time elapsed during receipt and recording of OSC message, notification of response team commander, notification of other base officers and of destination personnel. . . . . 15 min

b. Notification and assembly of strike team personnel. . . . . 45 min

c. Personnel briefing. . . . . 15 min

d. Equipment check . . . . 30 min

e. Tractor availability and delivery . . . . 30 min

f. Response Range R/Mean Speed . . . . . R n.mi./33.3 knots

Intervals (d) and (e) are assumed to occur concurrently, and all others sequentially. If the equipment is not pre-loaded, approximately 1 to 3 hours will be required to do so. The appropriate loading devices (minimum capacity 10 tons) must be made available. A time of 120 minutes is assumed for aquiring the loader, and loading and securing the equipment on one semi-trailer. About 60 minutes will be added for each additional semi-trailer to be loaded and secured, assuming one loading team and loader. This activity (g) is carried out simultaneously with (d) and (e). Figure 7-3 shows the parallel/sequential assumptions made for the time intervals (a) through (g). To estimate the mean road speed of (f), the driving time between 21 coastal city pairs was plotted against the straight line distance between them (Figure 7-4).* The magnitude of the mean error is less than 2 n. mi./hr.

*Land distances and speeds have been expressed in nautical miles and knots, contrary to convention, so that the response range for land will be in units comparable to those conventionally used for air and sea, i.e., nautical miles.

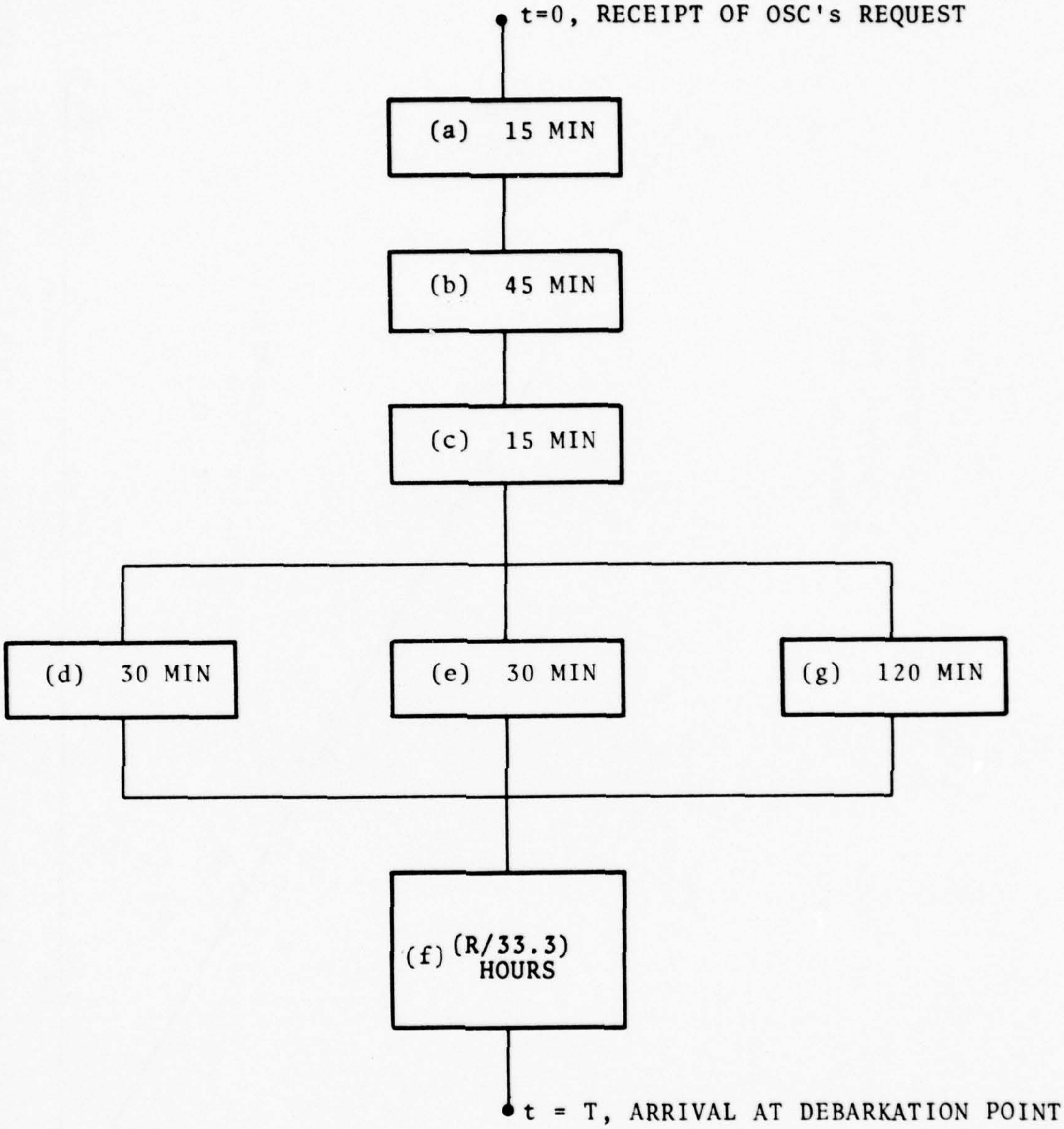


FIGURE 7-3 TIMING DIAGRAM FOR SINGLE-MODE LAND

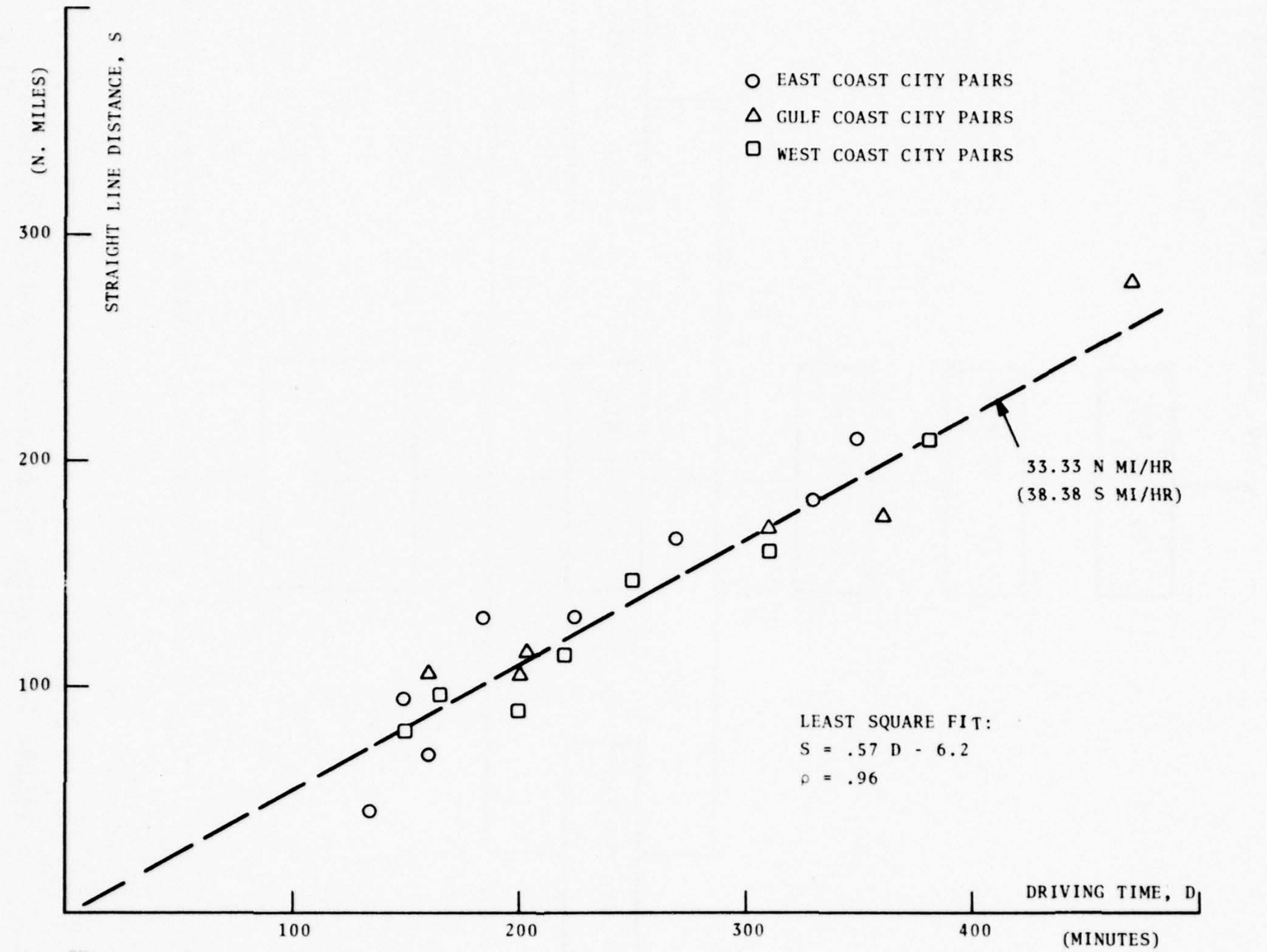


FIGURE 7-4 STRAIGHT LINE DISTANCE (S) VS DRIVING TIME (D) FOR 21 U.S. COASTAL CITY PAIRS

When the above assumptions are combined the result is a plot of response range R as a function of response time T, given in Figure 7-5. The response time is measured from the time the OSC makes his request for assistance to the time the equipment arrives at the debarkation point. Unloading time at the debarkation point is not included in the response time. It will be seen from Figure 7-5 that the single-mode land response range is 140 n.mi. for 6 hours and 340 n.mi. for 12 hours, assuming pre-loaded semi-trailers. If the semi-trailers (or trucks) are not preloaded, the ranges drop to 90 n.mi. and 290 n.mi., respectively, for the first load, and 35 n.mi. less for each subsequent load.

7.4.3 Option 3, Single-Mode Air

In this scheme, the equipment (or part of it) is carried by helicopter from storage site to debarkation point. The storage sites thus should be helicopter bases, in order to avoid having to ferry the helicopter to the equipment base. [An exception to this rule occurs when the equipment site is located between two helicopter bases in order to improve helicopter availability at the expense of response time.] Although the helicopter assignments at present USCG bases may be different in 1980-1990, it is not likely that the bases themselves will be drastically relocated, so that the response ranges to be calcualted will apply for the most part to existing USCG air bases as equipment sites.

The major time intervals in helicopter response are estimated as follows:

a. Alert time: Time required to receive OSC request, notify team commander and alert key base personnel at destination. . . . . 15 min

b. Notification and assembly of response team members and loading crews and equipment . . . . 45 min

c. Personnel briefing. . . . . 15 min

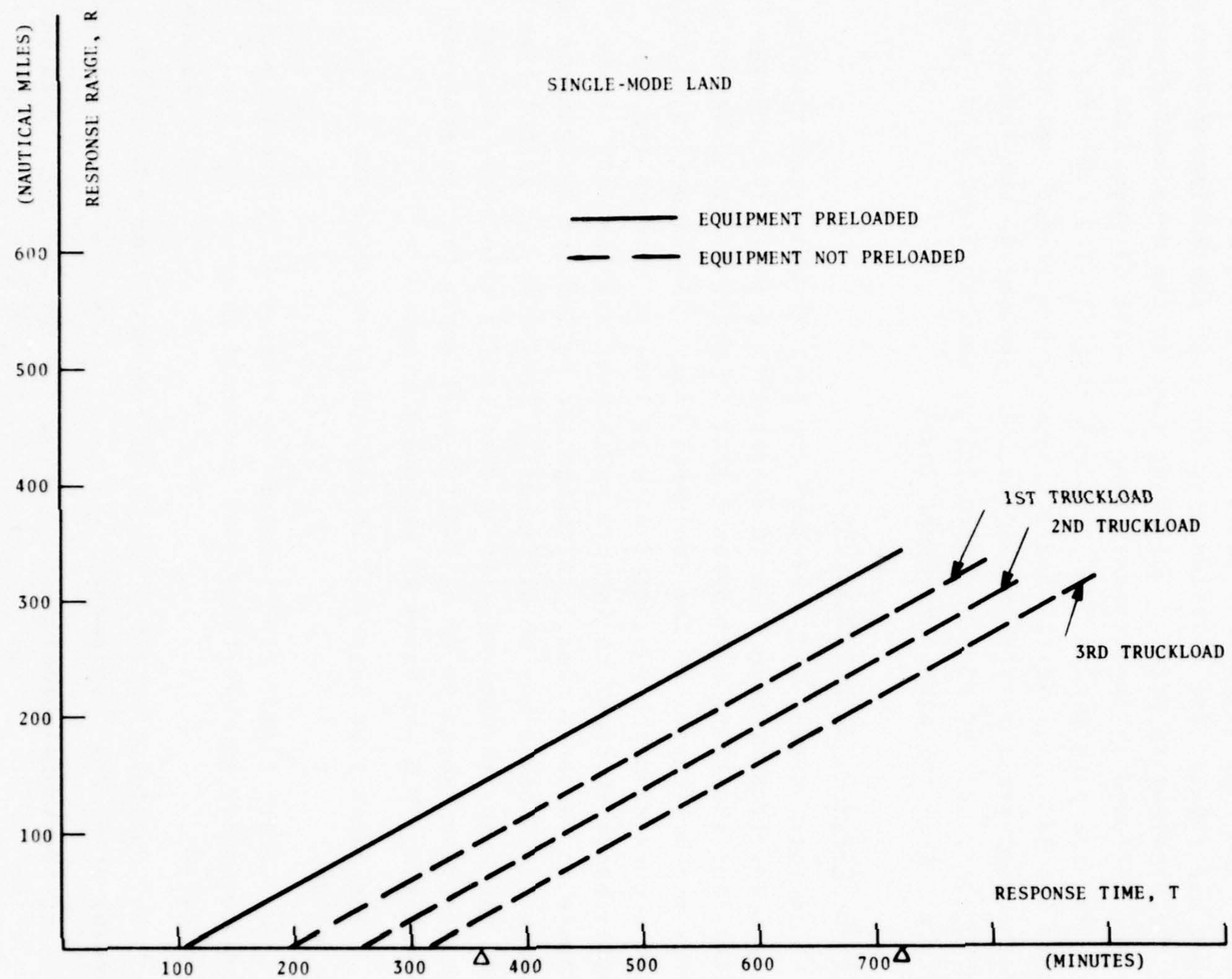


FIGURE 7-5 RESPONSE RANGE VS RESPONSE TIME, LAND

d. Reconfiguration of helicopter from SAR to pollution response, and loading of pollution response equipment . . . . minimum 180 min
maximum 240 min

e. Pilot and crew availability . . . . .30 min

f. Response Range R/Mean speed . . . . . . (R/130) hrs.

The largest single interval, and the most difficult to predict, is the time to reconfigure and load. The time shown here is that for the present HH3F, as estimated by USCG/OSR. Future USCG helicopters may be specified for faster conversion and this time may drop drastically. As an alternative, therefore, a reconfiguration/load time of 30 minutes will be considered.

The relations among the above intervals are shown in Figure 7-6 and the resulting response range-time plot is shown in Figure 7-7. It may be seen in Figure 7-7 that the response range with present loading capability is between 130 and 260 n.mi. in 6 hours, with an average of 195 n.mi. For 12 hours, or for 6 hours with a 30-minute load capability, the range is limited not by the response time, but by the payload, which diminishes rapidly with range. The one-way payload lines that have been assumed for the three classes of future USCG helicopters were given in Figure 7-1(b). They are re-plotted on Figure 7-8, along with the weights of the various elements of the baseline response system. (The three solid lines are carried to zero payload, but in actuality will be cut off by fuel tank capacity. A slightly more conservative value has been used for the Type C helicopter zero-range payload.)

It can be seen from Figure 7-8 that typically:

In 6 hours, with a 210 min. load time,

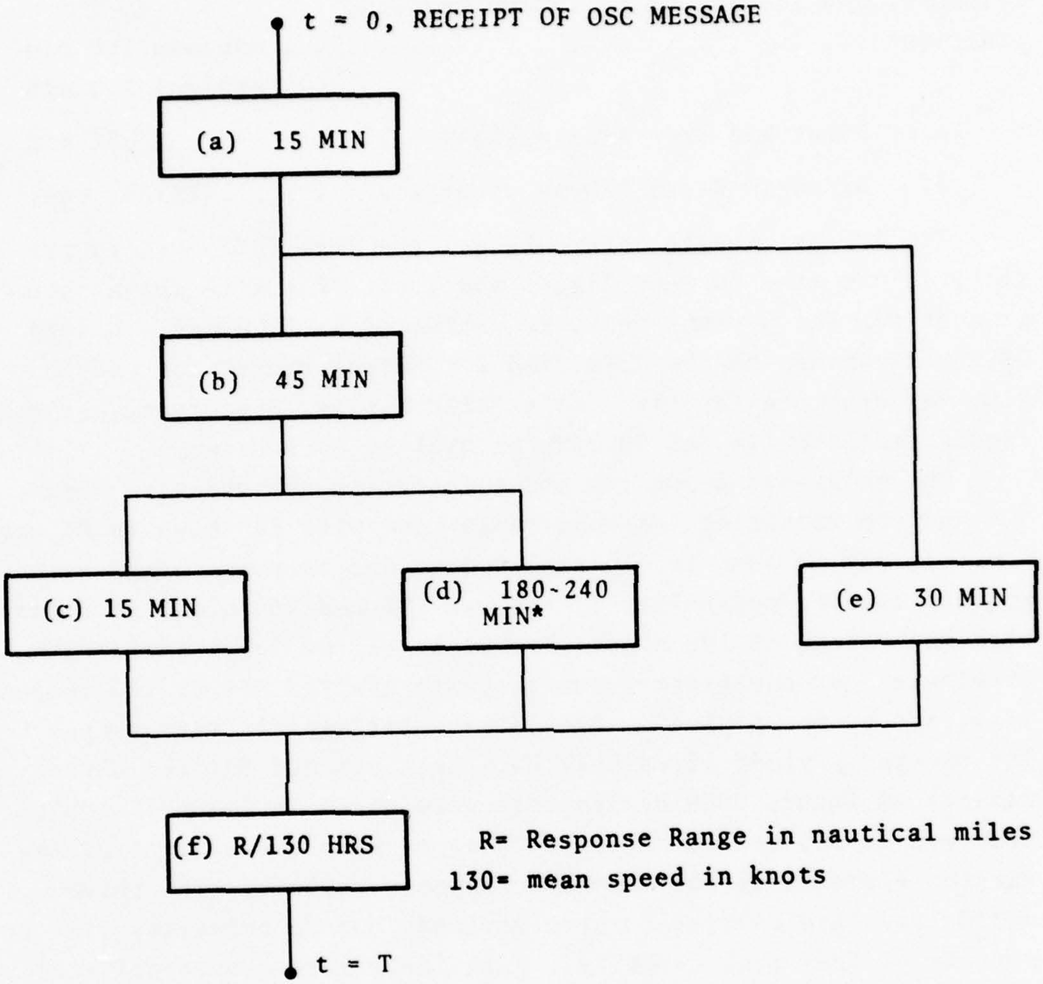
Class A can deliver 5,000 lbs to 200 n.mi.

Class B can deliver 10,000 lbs to 200 n.mi.

Class C can deliver 20,000 lbs to 200 n.mi.

In 12 hours, or in 6 hours with a 30-minute load time,

Class A can deliver 4,000 lbs to 400 n.mi.



*This may be about 30 minutes for special reconfiguration specification on new helicopters.

FIGURE 7-6 TIMING DIAGRAM FOR SINGLE-MODE AIR

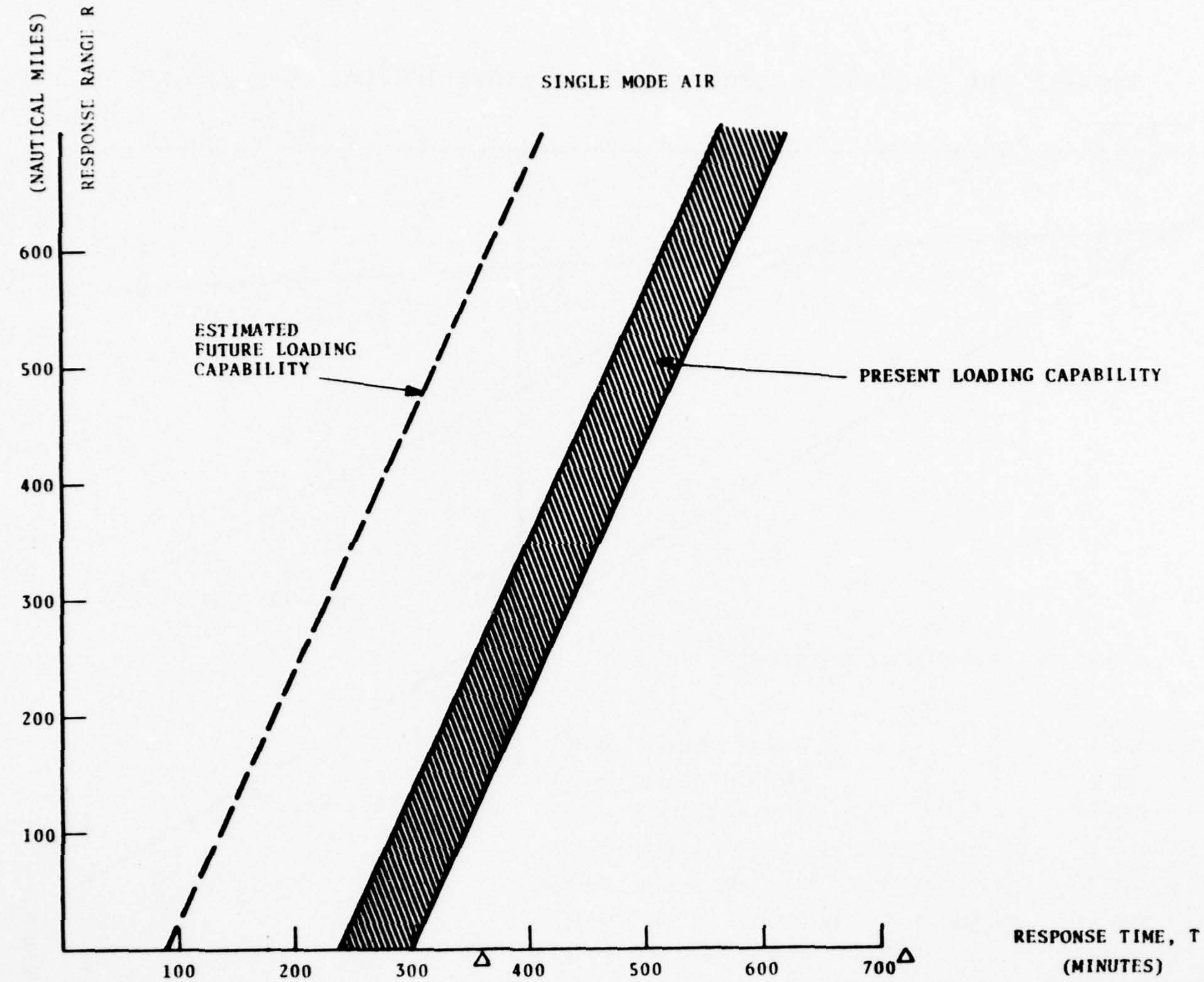


FIGURE 7-7 RESPONSE RANGE VS RESPONSE TIME, AIR

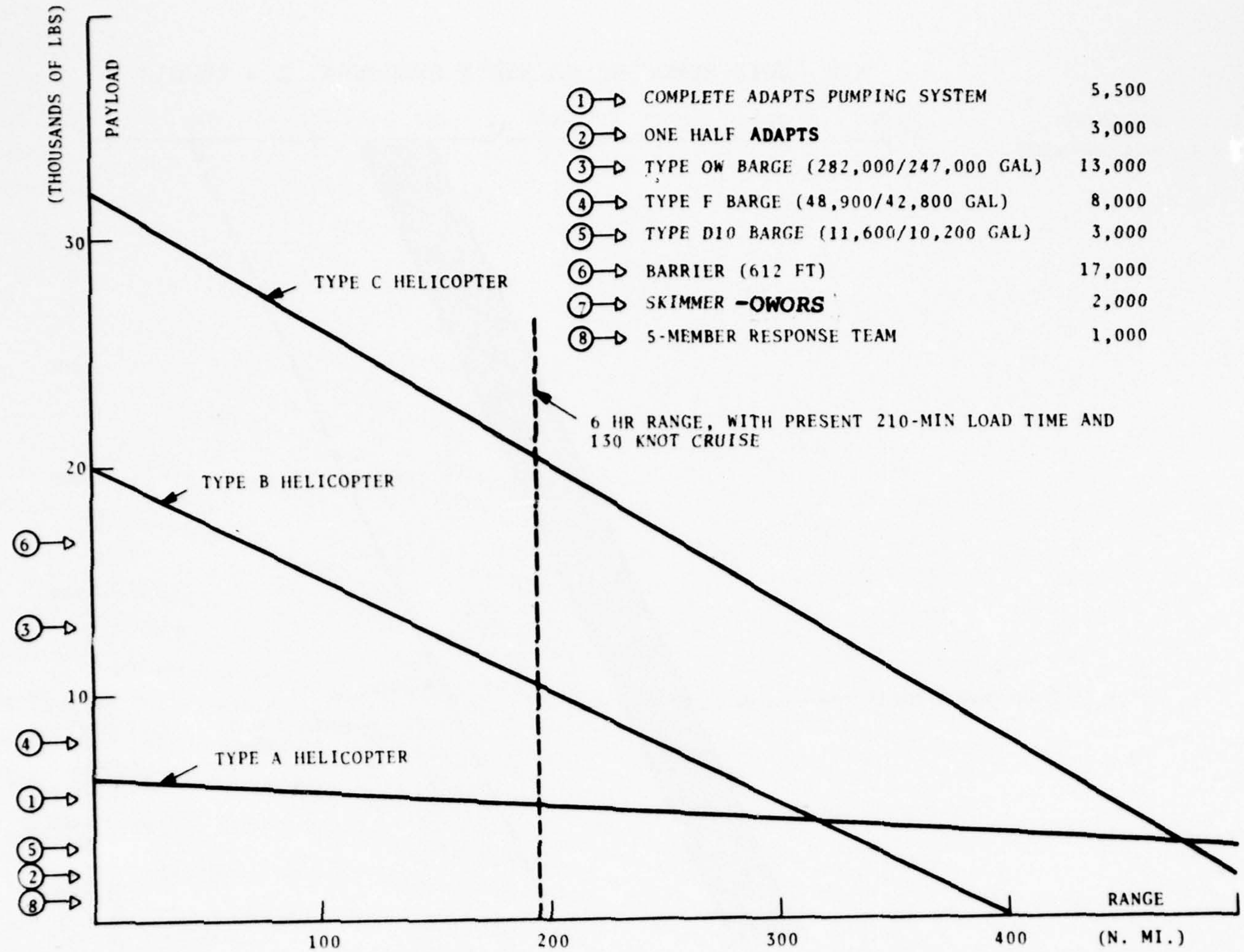


FIGURE 7-8 PAYLOAD-RANGE LINES FOR THREE CLASSES OF HELICOPTERS

Class B can deliver 5,000 lbs to 300 n.mi.

Class C can deliver 14,000 lbs to 300 n.mi.

In other words, reduction of the loading time to 30 minutes has the same effect on delivery range as allowing 12 hours to respond, since in both cases the range is limited by the helicopter payload-fuel capacity.*

7.4.4 Option 4, Dual-Mode Air/Land

In this scheme, the equipment is flown by fixed wing aircraft from the equipment storage site to an intermediate airport where it is ferried by truck to the debarkation point. The intermediate airport may be a USCG, DOD or commercial field. The density of DOD airports (Appendix I) is such as to make them attractive as intermediate airports. This option requires loading at the original site, transfer at the intermediate airport, and unloading at the debarkation point.

The major time intervals in this scheme are estimated to be the following for the fixed wing/truck scheme:

a. Alert time: Same as for Options 2 and 3 . . . . 15 min

b. Notification and assembly of response team members and loading crews and equipment . . . . 45 min

c. Briefing. . . . . 15 min

*This suggests the following procedure to trade-off equipment loading time and payload: First, the range is selected on the payload-range chart so as to deliver enough equipment to perform the offloading function [e.g., 1 ADAPTS, 1 Type F barge, 6 team members] or the recovery function [e.g., 1 barrier, 1 skimmer, 1 barge, 5 team members]. The point on Figure 7-7 corresponding to this range and the required 6-hour response time is marked, and a line drawn through the mark parallel to the dashed line. This new line will intersect the response time axis at a time t_x. Subtracting 60 minutes (the non-loading ground time) from t_x gives the desired loading time, i.e., the loading time that will maximize the range for the given payload without exceeding the specified response time. Shorter loading times reduce the response time, but do not increase range.

d. Loading of pre-packed equipment onto aircraft . . . . minimum 30 min
maximum 45 min

e. Aircraft check, taxi, clearance, take-off, climb . . . . 15 min

f. Cruise (mean for C130-B, C130H) . . . . .295 knots

g. Approach, Landing, Rollout. . . . . 10 min

h. Unloadings. . . . . 10 min

j. Load truck. . . . . 30 min

k. Intermediate Airport to Debarkation Point . . . . 33.33 kts

The loading interval (d) shown here assumes availability of a loading truck appropriate to the C130 (or other aircraft employed). If this equipment is not available, an additional 15 to 30 minutes must be added to (d) for fork lift loading. If the aircraft must be hand loaded, the time is estimated at 4 to 8 hours.

The loading interval (j) assumes a crane or front loader capable of lifting 10 tons (if the barrier is transported), available at the transfer airport. The acquisition time for this loader is not critical since it may be acquired while the fixed-wing aircraft is enroute to the intermediate airport.

The relations among the intervals (a)-(k) are shown in Figure 7-9 and the corresponding range-time diagram of Figure 7-10. It can be seen from Figure 7-10 that the response time is highly sensitive to the distance between intermediate airports. If in Figure 7-10 it is assumed, for illustrative purposes, that the intermediate airports are 200 n.mi. apart* and collinear with the equipment site, and if the specified response time is 360 minutes, only those range-time combinations within the shaded areas can be realized. It can be seen that there are gaps in the four range intervals: 280-340 n.mi., 460-560 n.mi., 640-780 n.mi., and above

*The average air distance between adjacent USCG air bases in the U.S. is 185 n.mi. ±69 n.mi., when Pacific and Great Lakes bases are grouped separately.

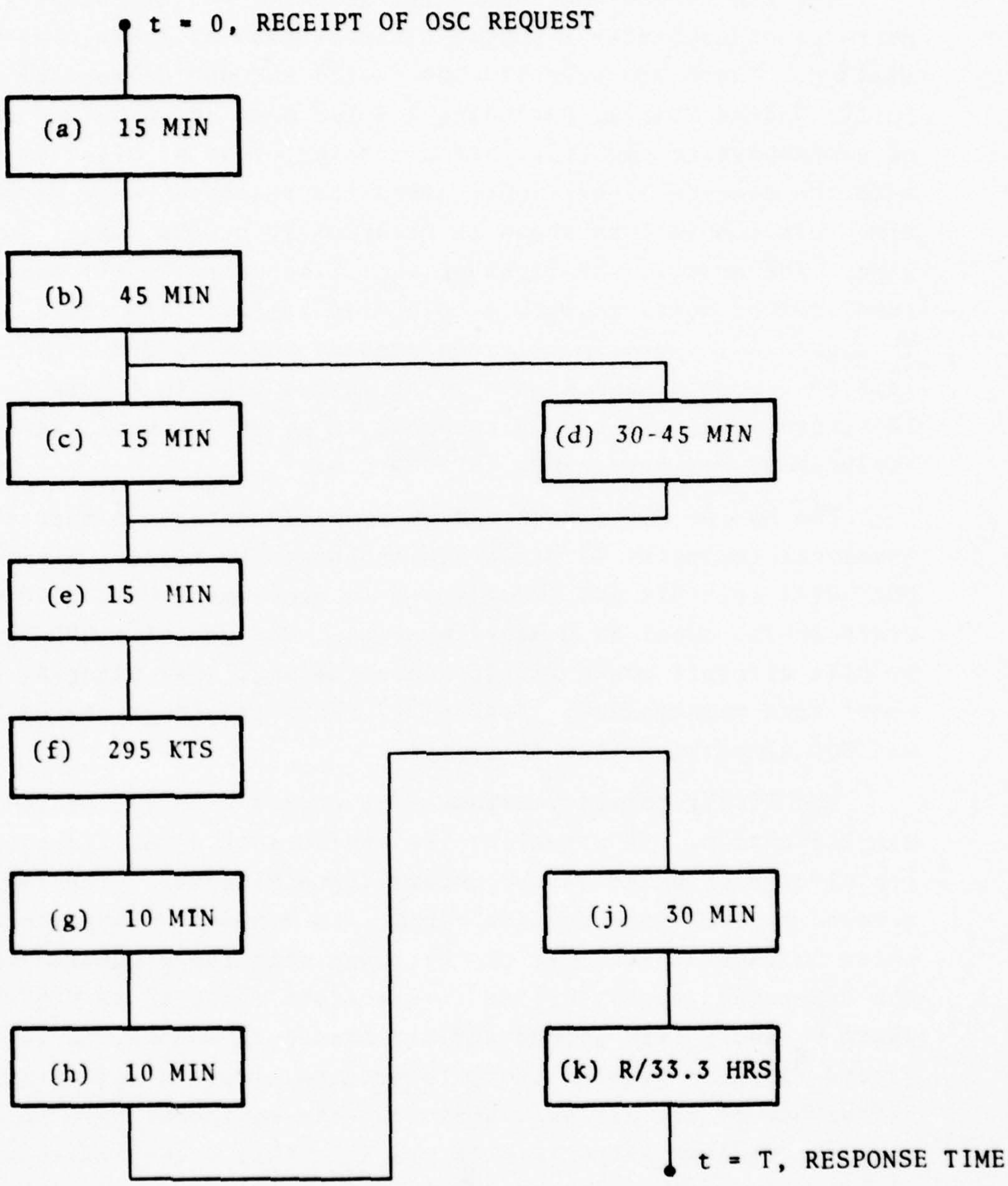


FIGURE 7-9 TIMING DIAGRAM FOR DUAL-MODE AIR/LAND

820 n.mi. These portions of coast line would be inaccessible by air/land modes within 6 hours if the equipment site and intermediate airports are at 200 n.mi. intervals along a straight line.

The use of DOD and commercial airports as intermediate airports provides better response times because of their closer spacing. There are over 150 DOD fields and 600 commercial fields in the United States, excluding Alaska, most of which are capable of accommodating the C130. If a spacing of 50 n. miles is assumed with the same co-linear model, then the response range-response time relation is that shown in Figure 7-10 by the small, saw-tooth line. The area to the right of that line contains all range-time combinations possible with a 50-n.mile intermediate field spacing. This area is, approximately, bounded by the straight line $R = 295T/60 - 1000$, shown as a slanted dashed line in Figure 7-10. The corresponding six-hour response range is 750 n.mi., and the twelve-hour response range is 2500 n.mi.

The use of DOD fields has an added advantage in that truck transport equipment is often available at the field. Moreover, USAF C141 aricraft may be employed to supplement USCG C130 aircraft in the event of a massive spill. The use of a DOD airport by C141 aircraft would facilitate refueling, crew changing and short-term maintenance. Appendix I shows the locations of USCG and DOD airports in the 48 states.

The linear geometry assumed for Figure 7-10 is, of course, a simplification. In actuality the contours of equal transport time are circles centered on the intermediate airports. The region covered by each intermediate airport is bounded by hyperbolas, as shown in Figure 7-11. It can be shown that the eccentricity of the hyperbola separating two intermediate airports is $V_a \Delta G / V_g \Delta A$, where V_g and V_a are ground and air transport speeds, ΔG is the ground distance between the intermediate airports and ΔA is the difference of the air distances from the equipment base to the two intermediate airports. In practice this eccentricity is at least 9, so that the hyperbola is practically a straight line midway between the two intermediate airports.

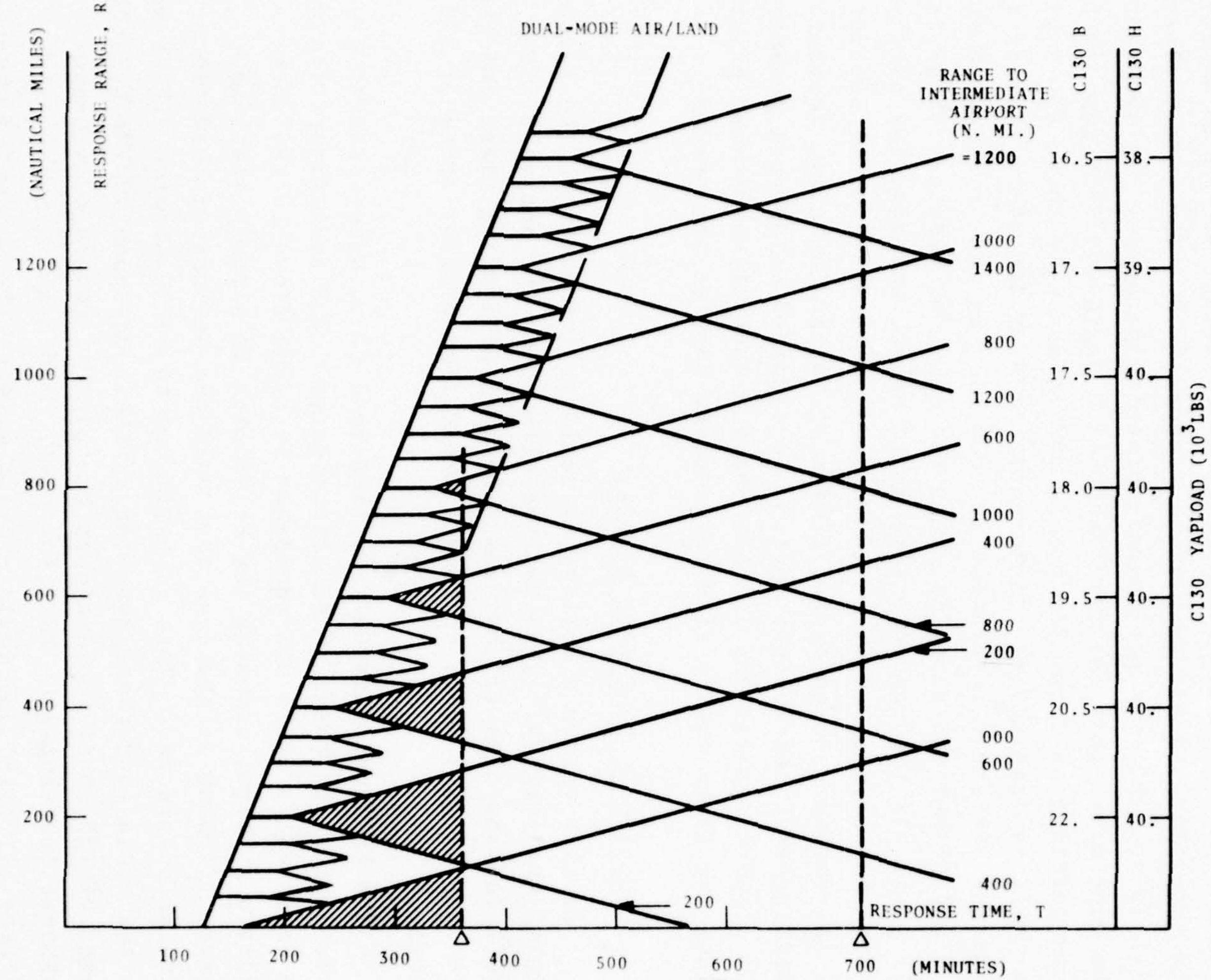


FIGURE 7-10. RESPONSE RANGE VS RESPONSE TIME, AIR/LAND

In view of the somewhat complicated geometry, the concept of response radius does not generally apply to the dual-mode air/land option. The alternatives are (1) to work out the geometry for actual bases and available intermediate fields, or (2) to employ the simplified linear geometry of Figure 7-10. The latter alternative is suitable for preliminary planning purposes. It leads to the conclusion that the air/land option begins to show gaps in 6-hour coverage at about 300 n.mi., and is unusable above 650 n.mi., assuming an intermediate field separation of 200 n.mi. But if the intermediate field separation is 50 n.mi., as may be expected for DOD and commercial airports, then the six-hour response range is 750 n.mi. If the response time is 12 hours, however, the air/land option has a range of over 2,000 n.mi., with a 200 n. mi separation of intermediate airports and 2500 n.mi. with a 50 n.mi. separation. These general conclusions must be re-examined using real geometry and airport separations in the numerous special cases that exist along the three coasts if more accurate results are needed.

7.4.5 Option 5, Dual-Mode Air/Air

In this option a helicopter replaces the truck in the second leg of the journey. This has two effects on the analysis: the truck loading time (j) becomes a helicopter loading time, and the truck speed 33.3 knots becomes a typical helicopter speed of 130 knots.

The helicopter reconfiguration-load time, under present procedures for the HH3F, is 180-240 minutes. The reconfiguration may be carried out while the equipment is being flown to the intermediate airport, assuming the helicopter is already stationed there. If such is the case then only the helicopter load time need be considered. This is estimated to be 30 minutes, the same as the truck load time, assuming suitable equipment. The helicopter speed of 130 knots would reduce the gaps in coverage in 6-hour response for ranges up to 1,100 n.mi. (200 n.mi. between intermediate airports) and would provide essentially unlimited coverage for a 12-hour response time. See Figure 7-12.

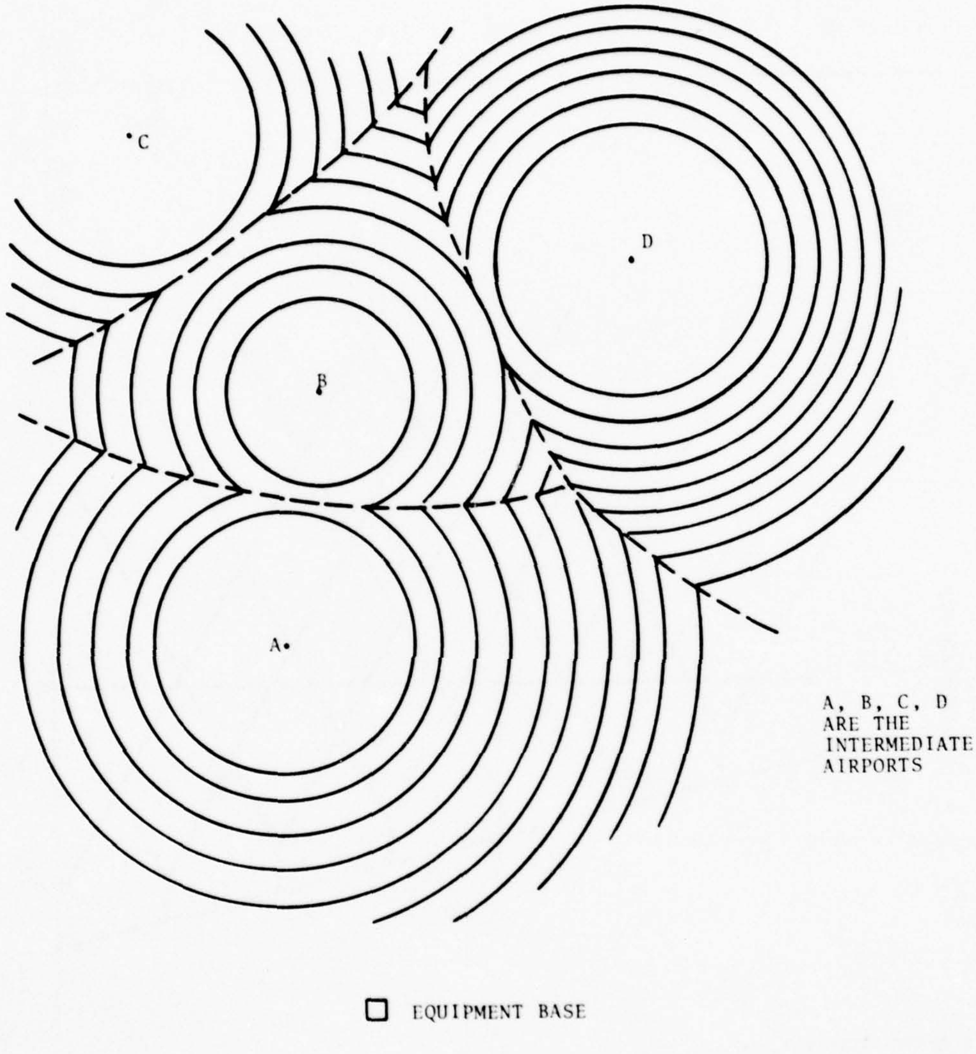


FIGURE 7-11 CONTOURS OF EQUAL TRANSPORT TIME DUAL-MODE AIR/LAND

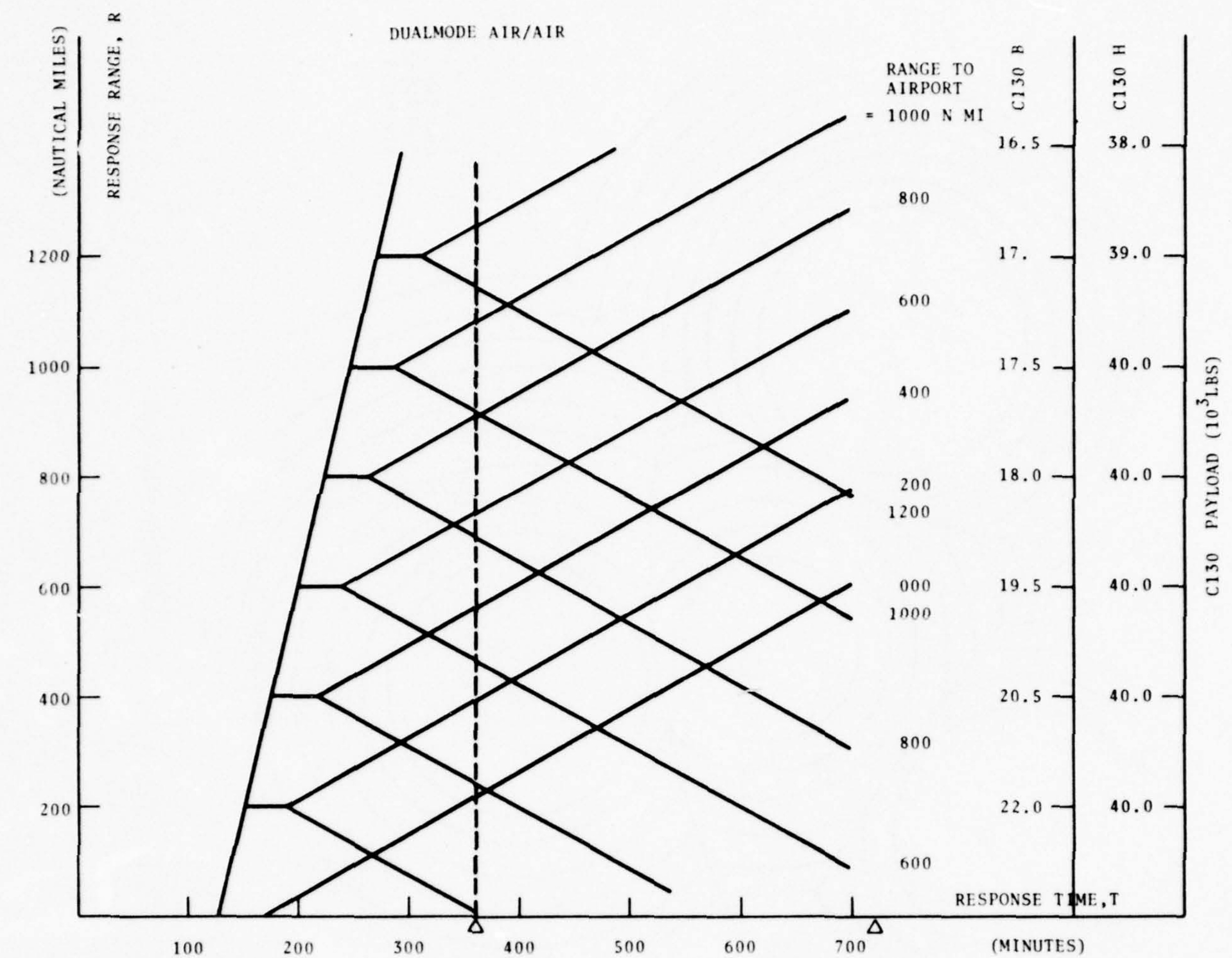


FIGURE 7-12 RESPONSE RANGE VS RESPONSE TIME, AIR/AIR

As in the single-mode air option the air/air option assumes helicopter landing and refueling capability at the debarkation point. It is likewise limited by the payload-range lines of typical helicopter classes as shown in Figure 7-8, although the ranges required are closer to 100 n.mi. than the 200 n.mi. that is needed for the single-mode air 6-hour response.

7.5 COMPARATIVE RESPONSE TIMES

The response time is defined to be the time from receipt of the OSC's request at the equipment site to arrival of the requested equipment at the debarkation point. It does not include time to unload the equipment at the debarkation point, to load it onto a vessel or helicopter, and to transport it to the spill location. In the Direct Waterborne option, however, the equipment is either delivered to the debarkation point, by water (on a vessel such as the FSD), already prepared for transport to the spill, or it is delivered directly to the spill by water. In Transfer Waterborne a similar difference exist, since for that option the equipment is delivered on a mobile launcher to the debarkation point, ready to be launched without unloading and reloading.

In order to make comparisons among all options on an equal basis it is necessary to reduce them all to delivery to a common location and condition. The only point common to all options is the spill site, ready to be deployed. For the OWOCS, OWORS and POHSSC this means in the water at or near the spill; for the ADAPTS it means on the deck of the stricken vessel. To make these estimates the travel and transfer times of Table 7-6 were assumed. From the travel and transfer times it is possible to estimate the time to deliver the equipment to the spill (assumed to be a stricken vessel) for each logistic option. These times are shown in Table 7-7 and are to be added to the times previously calculated for each option in order to bring the equipment to the spill, ready to be deployed.

TABLE 7-6 TRAVEL AND TRANSFER TIMES ASSUMED, DEBARKATION POINT TO SPILL

TRANSFER TIMES AT DEBARKATION POINT	MINUTES
Sled to Buoy Tender	20
Sled to dock via crane	20
Trailer-Launcher to water	15
Truck to dock via crane	10
Truck to Buoy Tender	20
Helicopter (internal) to dock	30
Dock to Buoy Tender	15
Dock to sled via crane	20
TRAVEL TIMES, DEBARKATION POINT TO SPILL	**MINUTES**
Towed sled	60d/12.2
Buoy Tender	60d/10
Helicopter (external)	60d/65
TRANSFER TIMES AT SPILL	**MINUTES**
Sled to water	5
Water to stricken vessel (ADAPTS)	30
Helicopter (external) to striken vessel	10
Buoy Tender to stricken vessel	30
Buoy Tender to water	10
Helicopter to water	5

NOTES

d = distance from debarkation point to spill, n.miles.

TABLE 7-7 ADJUSTMENTS TO RESPONSE TIMES OF TRANSPORT OPTIONS TO ACHIEVE DELIVERY TO THE SPILL

OPTION	-Method of Transport to Spill- Buoy Tender	Towed Sled	Helicopter (Estimated)
1. SINGLE MODE, WATER			
(a) Direct Waterborne			
-To debarkation point	30 + 60d/10	5 + 60d/12.2	35 + 60d/65
-To spill location	-	5	-
(b) Transfer Waterborne			
-To debarkation point	-	20 + 60d/12.2	25 + 60d/65
2. SINGLE MODE, LAND			
(a) Tractor-Trailer	30 + 60d/10	35 + 60d/12.2	25 + 60d/65
3. SINGLE MODE, AIR			
(a) Helicopter (Internal)	55 + 60d/10	55 + 60d/12.2	45 + 60d/65
4. DUAL-MODE, AIR/LAND			
(a) Fixed Wing/Truck	30 + 60d/10	35 + 60d/12.2	25 + 60d/65
5. DUAL-MODE, AIR/AIR			
(a) Fixed Wing/Helo (Internal)	55 + 60d/10	55 + 60d/12.2	45 + 60d/65
FOR DELIVERY OF ADAPTS TO VESSEL ADD:	20	30	5

NOTES: All adjustments in minutes

d = distance from debarkation point to spill in nautical miles.

In constructing Table 7-7 it was assumed that the internal mode was used for helicopter transport to the debarkation point, and external mode for transport to the spill. The reason for this is the payload-range curves of Appendix F, Figure F-1, which show that the belly sling mode, which is much faster to load and unload, has adequate range for distances up to 130 n.mi.

Further, it will be noticed that cutters do not appear in Table 7-7 as a transport mode from debarkation point to spill. This is because no means are usually available to unload equipment from a cutter deck at the spill. Some additional assumptions behind Table 7-7 are:

(1) Equipment brought by Transfer Waterborne is carried by a trailer-launcher, and hence transfer to a Buoy Tender is not considered. Transfer to helicopter, however, may be necessary if the distressed vessel is inaccessible by sea because of shallow water.

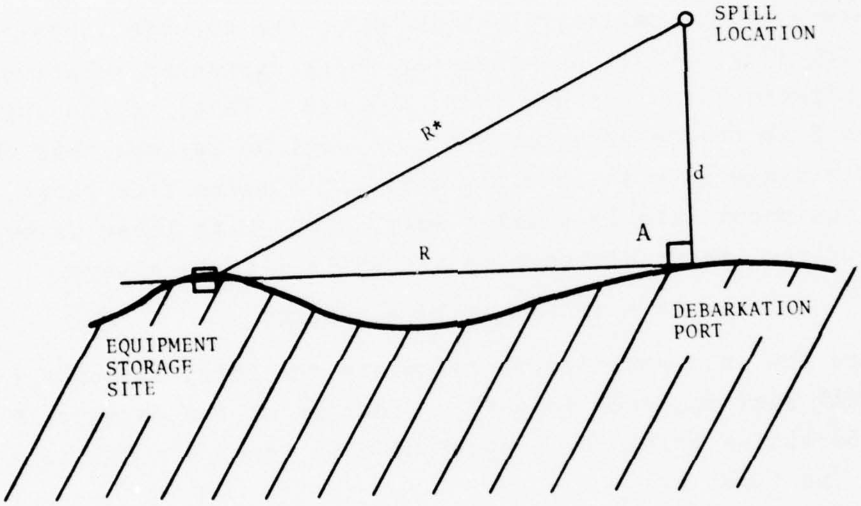
(2) The intervals shown apply only to single pieces of equipment, within the capacity of the vehicles.

(3) A lift or crane is available to transfer equipment to towed sled for delivery to the spill, for all options except 1(a), Direct Waterborne.

We are now in a position to put the direct waterborne logistic mode (equipment site to spill site) and the land mode (equipment site to debarkation point) on a common basis in order to compare their relative effectiveness. One choice for this basis is to add to the land response time a fixed delay for the transfer of equipment to a vessel and a transit time by water from the debarkation port to the spill site. Thus, we attempt to estimate the total spill response times,

a. Direct Water: T^*_{DW} = Fixed Delays + Water Transit

b. Land: T^*_{L} = Fixed Delays + Land Transit + Water Transit



Note: Because most spills occur close to the shore the angle A will most often be close to zero degrees or 180 degrees with 90 degrees as an average.

FIGURE 7-13 GEOMETRY FOR COMPARING DIRECT WATERBORNE AND LAND OPTIONS.

The fixed delays are taken from Table 7-7 and amount to 110 minutes for the direct water mode and a minimum of 135 minutes for land, made up of 105 minutes of fixed delay at the storage site (Fig 7-5) and 30 minutes at the debarkation port to transfer the equipment to a buoy tender (Table 7-6). In the case of the direct water mode, we assume that equipment is stored on a planing sled (FSD) and is towed to the spill site at 12.2 kts. The direct water distance to be traversed depends upon R, the land distance to the debarkation point and d, the distance from there to the spill site.

For the sake of simplicity it will be assumed that the vectors R and d are at right angles, which is about the average angle for the geometry (Fig. 7-13), and that for short distances relative to the equipment site response zone, d = R/2. Thus, if the spill is 5 miles from the debarkation port, it will be assumed that the equipment storage site is 10 miles away; if 3 miles from shore, that the equipment site is 6 miles away, etc. With these assumptions the direct water distance to the spill site is always

$$R^* = (R^2 + \tfrac{1}{4} R^2)^{\frac{1}{2}} = 1.12\ R.$$

We are now in a position to calculate the total response times to the spill site for each mode as a function of the distance R to the debarkation point for a spill at a distance d = R/2 to seaward. The times are

$$\begin{aligned} T_{DW}^* &= 110 + 1.12\ R(60/12.2) \\ &= 110 + 5.5R \qquad (1) \end{aligned}$$

and

$$\begin{aligned} T_L^* &= 135 + R(60/33.3) + 0.5\ R(60/10) \\ &= 135 + 4.8R. \qquad (2) \end{aligned}$$

One advantage of this approach is that it linearizes the problem and makes it easy to see that the two modes have about equal response times when the debarkation point is 36 n. mi. from the equipment site and the spill is 18 n. mi. from shore. At shorter distances the direct water mode has a small advantage, but never

more than about 25 minutes. Of course, any increase in the fixed delays for the land mode will increase this advantage minute for minute. For example, if the debarkation point is 10 miles from the equipment site and if the transfer time at the dock from truck to buoy tender takes one hour instead of 30 minutes, the direct FSD advantage would increase from 18 minutes to 48 minutes.

Beyond 36 n. miles the assumption that d=R/2 is unrealistically large with the number of debarkation points available along the U.S. coast. Beyond this range, therefore, the spill distance, d, is assumed constant at 18 n. mi and the direct water response time was calculated from

$$T_{DW}{}^* = 110 + (60/12.2)\ (R^2 + 18^2)^{1/2}, \quad R \geq 36 \text{ n. mi.} \quad (3)$$

$$T_L{}^* = 243 + 1.8\ R, \quad R \geq 36 \text{ n. mi.} \quad (4)$$

In this range the land mode has a large and growing advantage with increasing R. For example, when the debarkation point is 100 n. mi from the equipment storage site, the land mode would make it possible to have equipment at the spill site via a buoy tender as much as 3 hours before the FSD sled could arrive.

A similar calculation may be done for the dual air/land logistic mode. The total response time to the spill is

$$T^*_{AL} = \text{Fixed Delays} + \text{Air Transit}$$

In this mode the fixed delay is composed of

Ground operations (Figure 7-9)	170 min
Transit from destination airport to debarkation port (50 n. mi. @ 33 1/3 kts)	90
Total fixed delay to debarkation point	260 min
Transit from debarkation port to spill site (18 n. mi. @ 10 kts)	107
Total fixed delays to spill site	367 min

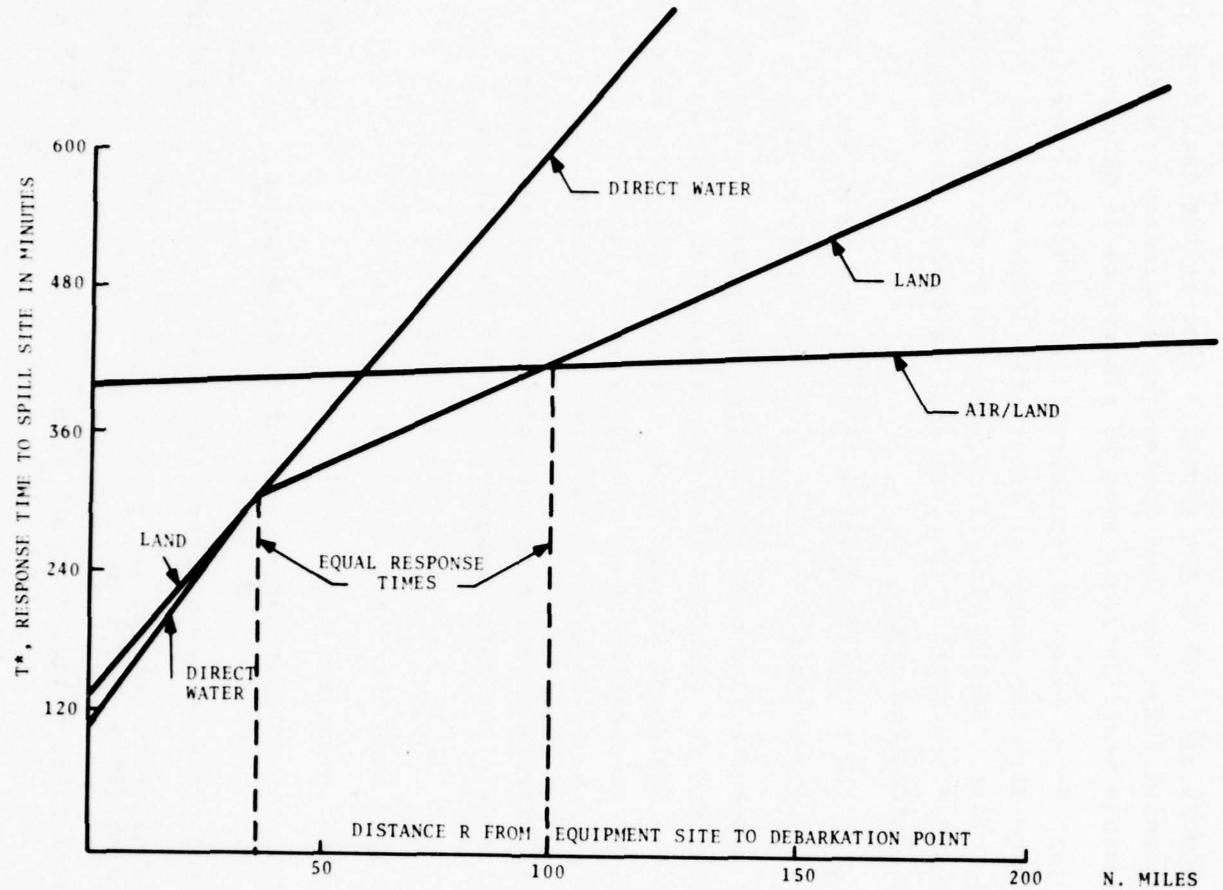


FIGURE 7-14 TIME T* FROM EQUIPMENT SITE TO SPILL

With a cruise speed of 295 knots for the C-130 aircraft, the total response time to a spill site 18 n mi. from the debarkation port is

$$T_{AL}^{*} = 397 + 0.2R \qquad (5)$$

Equations 1-5 are plotted in Figure 7-14

An alternative means of comparing these three logistic modes is to calculate their response times to the debarkation point. This approach requires that the direct water mode be reduced to a basis comparable to the other two, which can be done by subtracting the buoy tender loading and transit time from all three spill transit times. From Table 7-8, this value is found to be 30 + 60d/10 so that:

$$T_{DW} = 80 + 2.5\ R \quad , \quad R \leq 36 \text{ n. mi.} \qquad (6)$$

$$T_{L} = 105 + 1.8R \quad , \quad R < 36 \text{ n. mi.} \qquad (7)$$

$$T_{DW} = 28 + 4.9\ (R^2 + 18^2)^{1/2}, \quad R \geq 36 \text{ n. mi.} \qquad (8)$$

$$T_{L} = 105 + 1.8\ R \quad , \quad R \geq 36 \text{ n. mi.} \qquad (9)$$

$$T_{AL} = 260 + 0.2\ R \quad , \quad R \geq 36 \text{ n. mi.} \qquad (10)$$

These equations are plotted in Figure 7-15. Note that the air/land mode becomes advantageous when the equipment site is more than 100 n. mi. from the debarkation port <u>and</u> there is an airport no more than 50 n. mi away. At 150 n. mi. the advantage over the land mode is more than one hour, provided there are no unaccounted for delays on the ground.

7.6 SUMMARY OF LOGISTICS

The logistic information developed in the previous subsections includes three off-loading and the two recovery systems which differ only in the size of the temporary storage barges. The collection rates are similar, but total oil capacities differ. The delivery of additional barges, of course, increases the total capacity. The largest package for off-loading systems is the Dracone barge; the largest package for recovery systems is the barrier.

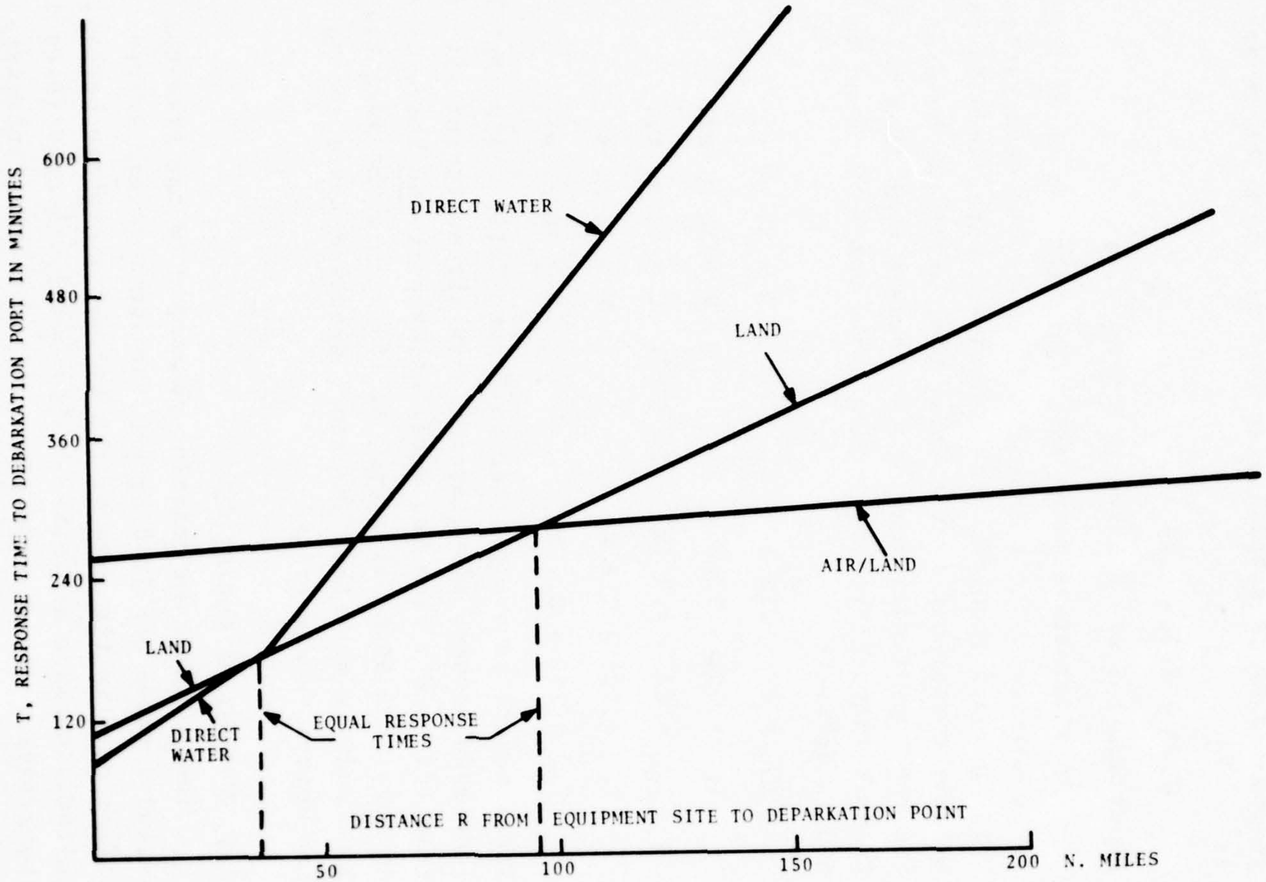


FIGURE 7-15. RESPONSE TIME (T) FROM EQUIPMENT SITE TO DEBARKATION PORT

The five basic response systems include three versions of the off-loading system and two of the recovery system. Several observations may be made relative to their delivery:

a. None of the single mode helicopter options can deliver the barrier because of its 9' width, with one exception not shown in the table. This is the Skycrane (a Class B) which can accommodate the barrier in place of its external pod.

b. Single mode helicopters of all classes are uniformly inferior to single-mode truck in payload and range for both 6- and 12-hour responses. This is because the trucks are assumed to be pre-loaded, while the helicopters must be converted from SAR.

c. The dual-mode air/land option provides about three times the range of the single-mode truck option, but with payloads limited by the C130B to 40% of the truck load, and by the C130H to 80% of the truck load.

d. No dual-mode air/air can deliver a complete recovery system because none of the helicopters can deliver the barrier, with the exception noted above.

e. The C130B/Helo/C can deliver the same payloads as the C130B/truck because the payloads are limited by the aircraft (assuming a 90,000 lb operating weight for the C130B). Also the C130B/Helo/C has greater ranges than the C130B/truck for both 6- and 12-hour responses.

f. The C130H/Helo/C has greater ranges but lower payloads than the C130H/truck option.

The conclusions to be drawn from the above observations are fairly clear.

First, there is little need to consider further single-mode helicopter, since it is inferior to single-mode truck in payload and range.

Second, from observations e. and f. it is seen that C130/Helo has no advantage over C130/truck except perhaps, range. Therefore, unless range is a primary consideration, the C130/truck option should be employed instead of the C130/Helo option. Considerations of cost, development and procurement time, and maintenance probably will reinforce this conclusion.

REFERENCES FOR SECTION 7

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7-2 Proceedings of the 1977 Oil Spill Conference, March 8-10, 1977, New Orleans, Louisiana. American Petroleum Institute publication No. 75-4161, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037.

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7-4 Abrahams, Cmdr. R. N., and E. R. Miller, Jr., "Oil Spill Containment System Development and Testing Program," in the Proceedings of the Joint Conference on Prevention and Control of Oil Spills, March 13-15, 1973. Published by American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20037.

7-5 Milgram, J. H., and R. A. Griffiths, "Combined Skimmer-Barrier High Seas Oil Recovery System," 1977 Oil Spill Conference, New Orleans, La., published by American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20037.

8. SITE SELECTION

In this section, storage sites will be selected with the primary purpose of minimizing the time required to deliver equipment to the potential spill locations identified in Section 3. A total of eight site configurations will be developed, each covering the coastal area of the 48 states, Hawaii and Puerto Rico. They will then be evaluated using measures based on response time, and the logistics assumptions of Section 7. The end result will be three recommended configurations, which will include sites with combinations of land, air and water capability. The coverage required of each site for both harbor and open water recovery will be an auxiliary result, to be used in the subsequent sections of this report. Questions of quantity and type of equipment will be taken up in Sections 9 and 10, as will the question of site requirements to meet a massive spill.

The key elements in the site selection process are:

1. Spill potential estimates
2. Logistics assumptions
3. Method of constructing site configurations
4. Method of evaluating site configurations.
5. Selection of recommended site configurations.

8.1 SPILL POTENTIAL ESTIMATES

Since the criterion for site selection is to minimize the time required to respond to a spill, the geographic locations of expected spills are the key to site location. In Section 3 spill rates were developed for the following types of oil movement:

1. Petroleum throughput at ports
2. Production from OCS wellfields
3. Transient tankers and barges

4. Deepwater port throughput

5. Lightering of vessels off the coast.

The total spill potential in the study area is taken to be the sum of the petroleum movements times the corresponding spill rate. From Section 3, it is seen that the approximate total threat levels of these five sources vary widely, as shown in Table 8-1.

By far the greatest spill potential originates from port flows, which are currently somewhat larger than the 775. million tons shown. Moreover, the 3-4%/year increase in petroleum consumption expected world-wide over the next ten years has been projected to a 50% increase in U.S. imports from 1977 to 1985 (See Table 3-3), from 775 x 10^6 tons/year shown in Table 8-1 under port flow volume to 1160 million tons in 1985. Of this amount about 440. x 10^6 tons may be expected to flow through deepwater ports, at the lower spill rate of .0027 spills per 10^6 tons, as shown in Table 8-1, while the remainder, 760 x 10^6 tons, would flow through ports at the spill rate of .0314 shown in the Table. The net effect, then, is to reduce the port flow spills by .48 spills/year to about 23.86 spills/year in 1985 while adding about 1.08 spills/year due to deepwater ports, a new increase of about .6 spills/year, or 3%. For the most part, the 4 projected deepwater ports coincide with the major oil ports (New Orleans, New York/Philadelphia, Los Angeles, Galveston) so that the effect on 1985 spills of changes in imports plus installation of four DWP's tend to cancel, the net result being equivalent to a slight increase in present port flows, without deepwater ports. The exception to this is the Puget Sound area, where a deepwater port facility may not replace the Seattle-Anacortes-Port Angeles-Bellingham-Cherry Point complex by 1985. The approach to be taken,

TABLE 8-1. SPILL POTENTIAL SUMMARY

Spill Source/Year	Average Spill Rate	Total Annual Oil Volume	Expected Number of Spills per Yr
	Spills/10^6 tons	10^6 tons/yr	($\geq$ 50,000 gals)
Port flows/1970-75	.0314 (1)	775. (1)	24.34 (7)
OCS Fields/1985	.0271 (2)	29.5 (2)	.80
Transients/1976	.00024 (3)	240. (3)	.06
DWP's/1985	.0027 (4)	400. (4)	1.08
Lightering/1976	-	150. (5)	-
Alaskan Crude/1985	.0314/.0027 (6)	80. (6)	3.0/.27 (6)

Notes

1. See Section 3.3.1.1; these are 1977 data, excluding internal flows.
2. Based on an expected total yield of 740. million tons and 20 spills from Gulf and Atlantic OCS fields over a 25 year period (See Section 3.4.4).
3. See Section 3.4.3.
4. See Section 3.4.5. The volume shown assumes 4 deepwater ports in 1985 at 2.0 million BBL/day/DWP (7.33 BBL/ton).
5. See Section 3.4.6 for discussion. The volume shown is based on 100 million tons for the Gulf Coast, 25 million for the West Coast and 25 million tons for the Puerto Rico-Virgin Islands area, current lightering rates.
6. See Text
7. Average spill rate times the total annual oil volume. Including regional differences, this number is about 22.8.

then, is to employ current port flow data, with a slight upward adjustment from that shown in Table 8-1, to allow for deepwater ports and increased imports in 1985. An adjustment for the Puget Sound area will be made at the conclusion of the analysis (Section 9.0). To this will be added the spill potential from OCS production projecting to 1985. The spill effects of transient tankers are small compared to that for port flows, and may be assumed to have the same geographic distribution of debarkation points. Similarly, lightering may be expected to be less in 1985 than at present if the projected deepwater ports are installed. Since the data needed to establish lightering spill rates are lacking, lightering spills will not be explicitly treated in deriving site locations.

Finally, Alaska Crude must be taken into account. The expected volume (see Appendix C) may enter the West Coast through deepwater ports, (spill rate 0.0027), through conventional ports (spill rate .0314) or through some combination. The assumption made is that 2/3 of it will enter through a DWP in the Los Angeles area, with only about 20×10^6 tons/year entering Puget Sound. The part entering Los Angeles is accounted for in the above DWP estimates, while the part entering Puget Sound will be accounted for separately.

With the above assumptions and approximations, spill potential estimates for 1985 were made up based on a total oil port flow of 900×10^6 tons/year, plus a projected 40×10^6 tons/year of OCS production in 1985. The oil port movement data were extracted from Reference 3.4, the Army Corps of Engineers "Waterborne Commerce of the United States", for 1976, with adjustments for the study area. To this was added approximately 40×10^6 tons/year of OCS projection from East, Gulf and West Coast fields in 1985 and 20×10^6 tons/year entering Puget Sound. Details of the resulting data base are given in Appendix J. The data give, for each oil port or waterway in the study area, the amount of oil received, shipped, or passed through, broken down by type of oil and by type of passage. The oils were classified as either (1) heavy, residual, and crude, or (2) light and distillates. The

passages were classed as (1) coastal, foreign and Great Lakes, or (2) internal or local. Movements in ports, rivers and channels outside the study area were excluded.

For OCS sites the data base contains U.S. Geological Survey expected annual yield for new lease sites, plus expected annual yield for present lease sites, both adjusted to 1985. A debarkation point is selected for each OCS lease site.

The port and waterway oil movements are multiplied by the regional or national spill coefficients of Section 3.4 to obtain the corresponding spill potential. The OCS production is multiplied by the offshore spill rates (see above) to obtain their spill potential. The spill potentials, expressed in expected spills/year, are contained in the data base (along with the oil volumes) broken down by port, type of movement, and type of oil.

8.2 LOGISTICS ASSUMPTIONS

Several methods of delivery were investigated in the preceding Section; three of these were selected as being of most value: direct waterborne, single-mode truck and dual-mode air/truck. The assumptions and guidelines for this study (Section 1) state that "although aircraft may be used whenever it is advantageous to do so, the initial six-hour response shall not depend on the availability of aircraft," This effectively restricts consideration of the dual-mode air/truck option to 12-hour response times, where it provides much greater ranges than the truck mode, or to reducing response times below 6 hours.

The equipment types required by the OCS will be assumed to be those of the baseline systems described in Section 6. The quantities of equipment required will be investigated in Section 9, to follow. It will be assumed, for purposes of site selection, that whatever quantities of equipment are required can be delivered by truck or water. (The air/truck mode, however, may not be able to deliver adequate quantities of equipment for large or massive spills, and this point will be considered later.)

It will be noted that there are (at present) three USCG strike teams, located at Elizabeth City, NC, Bay St. Louis, MS, and Hamilton AFB, CA. The Elizabeth City and Hamilton locations are large USCG bases, as well. Siting schemes that place equipment at one or more of these locations are more easily implemented and, other things equal, will be given preference.

8.3 METHOD OF CONSTRUCTING SITE CONFIGURATIONS

Two approaches were taken to producing candidate site configurations: one based on meeting the six hour response criterion by means of land transport alone, the other based on placing equipment as close as possible to the areas of major spill potential, employing both water and land transport.

Both approaches are related to the distribution of spill response times, as seen in Figure 8-1. This Figure is a hypothetical frequency distribution of response times achieved with a given configuration of sites. The response times include the times to all potential spills from the nearest equipment site (i.e., the site from which the most rapid response can be made). The first approach starts out with a site configuration such that the distribution lies entirely to the left of the 6-hour response time. The second approach starts with a configuration designed to concentrate the distribution close to the origin, i.e., to minimize the average value of response time, without specifically prohibiting response times greater than 6 hours.

In practice each approach is just the starting point for a series of configurations, each obtained from the previous by a trial-and-error process aimed at improving the evaluation measures. Before describing the evaluation measures, the two approaches to site configurations will be described in more detail.

8.3.1 Debarkation Point Method

In this approach site selection is based on the requirement that the requested equipment be delivered to the debarkation point within the specified response time by land. At one extreme, this

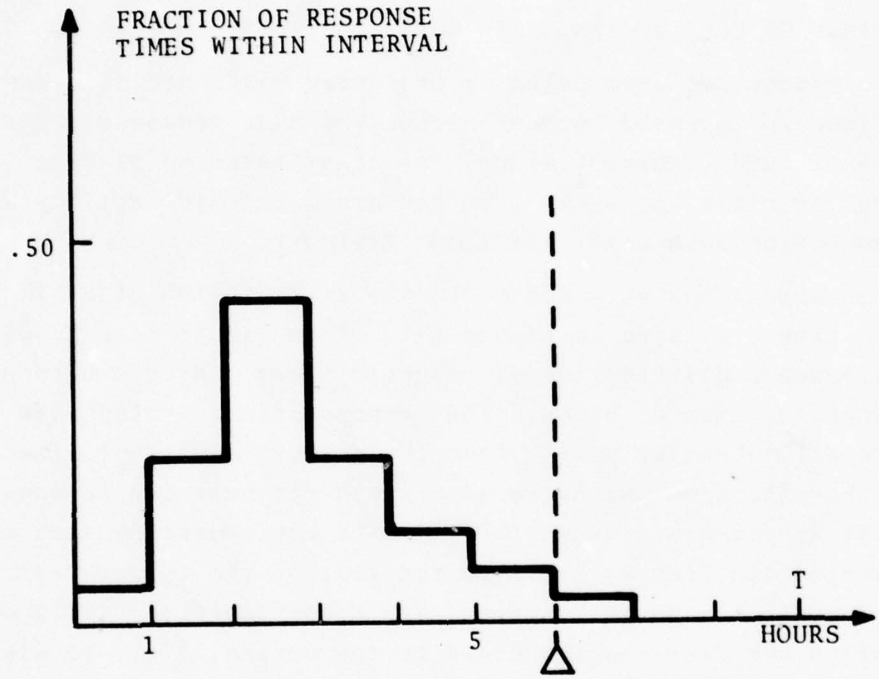

FIGURE 8-1. HYPOTHETICAL DISTRIBUTION OF RESPONSE TIMES

requirement may be met simply by storing all the equipment that may be required at every potential debarkation point. It was seen (Appendix E) that the number of potential debarkation points in the study area is very large (100 or more), so that the cost of such a solution would be prohibitive. Moreover, it provides greater protection than required by the site selection criterion. Costs may be reduced, and the response time still met, by locating the equipment at sites from which it can be transported to several debarkation points. One simple solution is to locate the sites so that every potential debarkation point is within the response range of one, and only one, equipment site. The procedure is to locate the potential debarkation points on a map, superimpose circles of coverage with radii equal to the response range in such a way that every debarkation point is within at least one circle, and then select equipment storage sites at, or near, the centers of these circles. For brevity, the geographic area covered by a single site will be termed a region. These regions depend on the transport method and response time chosen.

The above procedure is simple but must be modified to make it practical:

a. The response range for trucks developed in the preceding section is only approximate, and must be checked against actual road access in the region. Lakes, bays, and rivers must be allowed for.

b. Only an integral number of sites is possible. Therefore, any set of sites covering the study area will almost inevitably result in some overlap in coverage, or some gaps in coverage, or both.

c. Equipment sites should be located at USCG installations if possible. It has been found possible to do so in most cases investigated without substantially altering coverage areas.

It should be clear from this description that the proposed procedure produces not a single site but a set of sites covering the entire U.S. coastline or, at least, a large section of coastline. Three U.S. geographic areas have been selected as being

sufficiently isolated to apply the procedure: the West Coast, the Great Lakes area, the East and Gulf Coastal area. (Puerto Rico, the Virgin Islands and Hawaii are very isolated cases and will be treated individually.)

Configuration A: 6-Hour Requirement

In constructing this configuration, the only criterion rigidly applied was the delivery of the equipment by truck to the debarkation point within 6 hours. The debarkation points employed were those with a minimum depth greater than 10 feet and with lift or crane capability. They are described and illustrated in Appendix E and Figure E-1. The truck logistic range employed was 140 n. mi. (160 st. mi.), as derived in Section 7. The sites were restricted to USCG facilities. No gaps in debarkation point coverage were allowed, and overlap was reduced as far as practical. Preference was given to siting equipment at major oil ports, consistent with the above objectives.

The configuration resulting from the above approach is shown in Table 8-2 and Figure 8-2. A total of 17 sites results (excluding Hawaii and Puerto Rico). Some of the rationale follows:

Boothbay Harbor, ME is the southernmost facility from which Eastport, ME can be reached. (An actual spill occurred in the Bay of Fundy.) The Boothbay Harbor site does not cover Woods Hole, MA (debarkation point for the Argo Merchant spill), and the southernmost facility that does so is Northport, NY. But truck travel time via New York City brings Northport outside of the 6-hour response time to Woods Hole; the next closest is New Haven, CT. Dahlgren, VA was selected to cover the Chesapeake Bay area because the other candidates, (Chincoteague, Chrisfield and Ocean City) are more remote from Baltimore, a major oil port. The difference, however, is not great, and any of the four could serve Baltimore, Philadelphia and Norfolk, within six hours.

The next three sites selected are the minimum that can cover the area from Wilmington, NC to Key West, FL. The placement of a site at Chearwater provides only marginal coverage for Jacksonville.

TABLE 8-2. SITE CONFIGURATION A

LOCATION	USCG FACILITIES	USCG DISTRICT
EAST AND GULF COASTS		
Boothbay Harbor, ME	Station	1
New Haven, CT	Station, COTP, Group Office	3
Dahlgren, VA	Station	5
Charleston, SC	Base, MSO, Group Office	7
Clearwater, FL	Station, Air Station	7
Miami, FL	Base, COTP, Group Office	7
New Orleans, LA	Station, Base	8
Galveston, TX	Base, MSO	8
Corpus Christi, TX	MSO, Air Station	8
GREAT LAKES		
Sackets Harbor, NY*	Station	9
Erie, PA	Station, MSD	9
Bay City, MI	Station	9
Milwaukee, WI	Base, Station, COTP, Group Office	9
Duluth, MN	Station, MSO, Group Office	9
WEST COAST		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

*This is a seasonal auxiliary station. The preferred alternate is Oswego, NY.

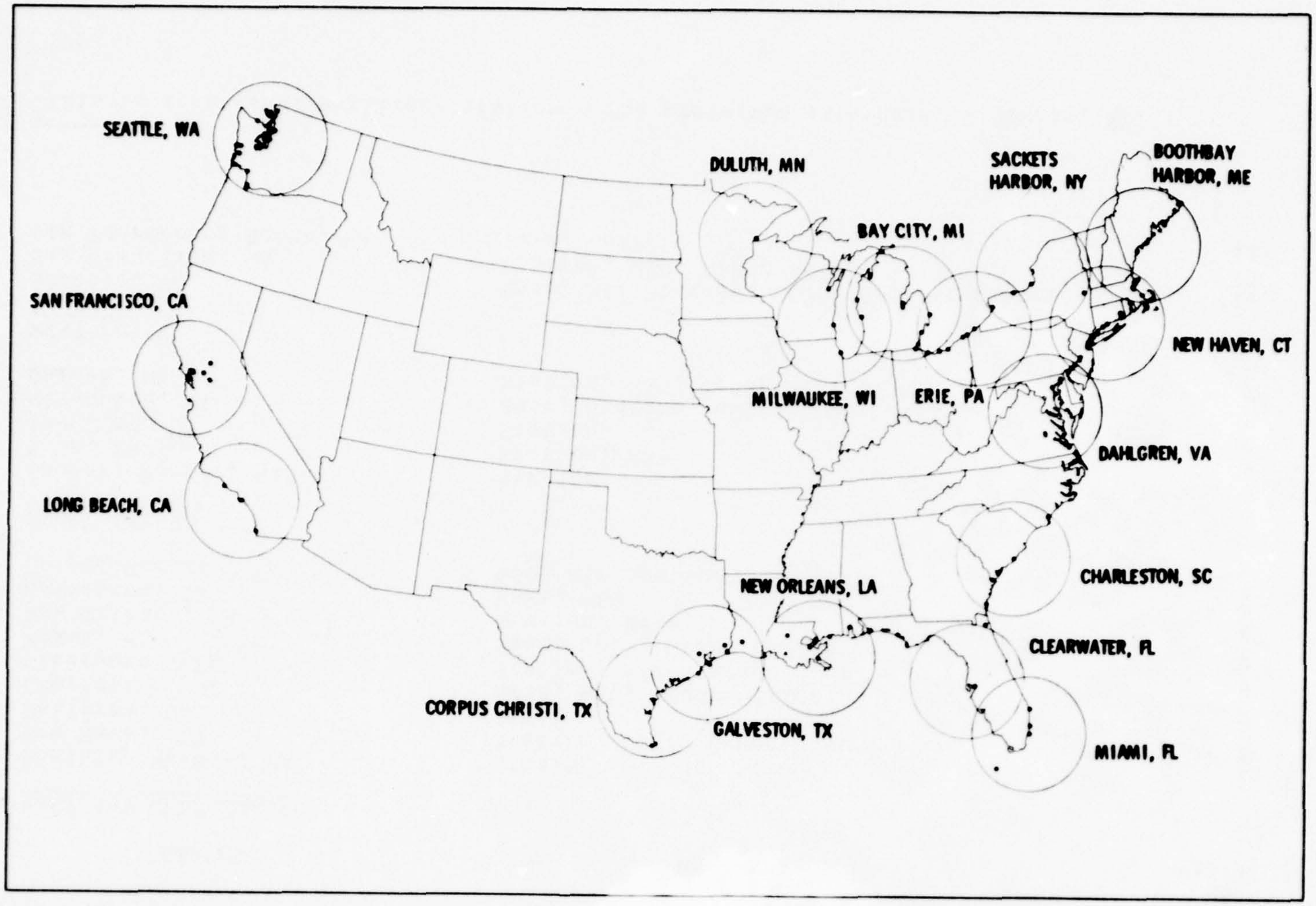

FIGURE 8-2. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION A

An alternative to Clearwater is Port Canaveral, which gives satisfactory coverage to Jacksonville, Tampa and Palm Beach, but is not itself a major oil port (2.68 million tons in 1976).

Working up from Mexico, it was found that three sites are required to cover all debarkation points in the Gulf Coast. The same result obtains if one works down from Mobile, Alabama.

The Great Lakes were covered as follows: Bay City, MI is the southernmost facility that will cover Mackinaw City, MI. Two more sites are required eastward of Bay City because one site alone (at Buffalo, NY) would not satisfactority cover Cleveland and Lorain, OH in six hours.

Towards the west of Lake Michigan, at least two sites are required: Milwaukee covers Chicago and Green Bay as well as itself, and Duluth covers Lake Superior.

The West Coast offers only one configuration that covers all debarkation points.

Configuration B: Minimum Overlap

The substantial number of debarkation points lying in two regions of Configuration A suggests that good coverage may be obtained with fewer sites. In addition, it is noted that several large oil ports, such as New York and Philadelphia, do not have direct coverage. Accordingly, Configuration B was devised as follows:

The Northeast was covered by sites at New York, NY (a major oil port) and Portland, ME (which handles more crude and heavy oil than any other New England port). This allows dropping the Dahlgren, VA site to the Norfolk, VA area, also a prominent oil port.

The remainder of the East Coast is covered by two sites: one at Savannah, GA and one at Ft. Myers Beach, FL. While the latter site has no substantial oil movement or port facilities, it does cover both Tampa/St. Petersburg and Miami/Palm Beach, Unfortunately, Key West is not reachable in 6 hours at normal highway

speeds, although it lies within the response circle from Ft. Myers.

By eliminating 6-hour coverage for Brownsville, TX it is possible to cover all Gulf debarkation points with two sites: New Orleans, LA and Freeport, TX. Similarly, two sites may be removed from the Great Lakes Configuration A if that at Duluth, MN is eliminated, and the two covering Lakes Erie and Ontario are combined into one at Buffalo, NY. The West Coast sites are unaltered from Configuration A.

The net result of the above adjustments is reduction of the number of sites from 17 to 13. The list of sites is given in Table 8-3 and shown in Figure 8-3.

Configuration C: 15-Site Configuration

Two shortcomings of Configuration B are apparent from Figure 8-3:

a. The Delaware Bay and Upper Chesapeake Bay are covered directly only from New York, NY or from Norfolk, VA. Baltimore Harbor is just beyond response range from both New York and Norfolk. The addition of a site at Baltimore remedies this deficiency, and provides redundant coverage for Philadelphia, Trenton, Wilmington, DE, and the Lower Chesapeake Bay. It also allows removal of the Norfolk, VA site to Elizabeth City, NC, where the Atlantic Strike Team is, at present, located. Such an alternative, however, would remove a site from a well-trafficked oil port on the Chesapeake Bay to a location without any substantial oil traffic, somewhat more removed from the Chesapeak Bay. Elizabeth City's coverage to the south is only slightly better than that of Norfolk, VA; both sites fail to cover Wilmington, NC within the 6-hour criterion.

b. The single site at Buffalo, NY fails to cover properly the North Ohio ports of Cleveland, Lorain and Sandusky, and the Upper St. Lawrence. The two-site arrangement of Configuration A is much more satisfactory in the Lake Erie and Lake Ontario area, having one site at Erie, PA and another at Sackets Harbor, NY.

TABLE 8-3. SITE CONFIGURATION B

LOCATION	USCG FACILITIES	USCG DISTRICT
EAST AND GULF COASTS		
South Portland, ME	Base, Group Office	1
New York, NY	Station, COTP, Group Office	3
Norfolk/Portsmouth, VA	Station, Base, MSO, Support Center, Group Office	5
Savannah Beach, GA	Station	7
Ft. Myers Beach, FL	Station	7
New Orleans, LA	Station, Base	8
Freeport, TX	Station	8
GREAT LAKES		
Buffalo, NY	Base, MSO, Group Office	9
Bay City, MI	Station	9
Milwaukee, WI	Base, Station, COTP, Group Office	9
WEST COAST		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

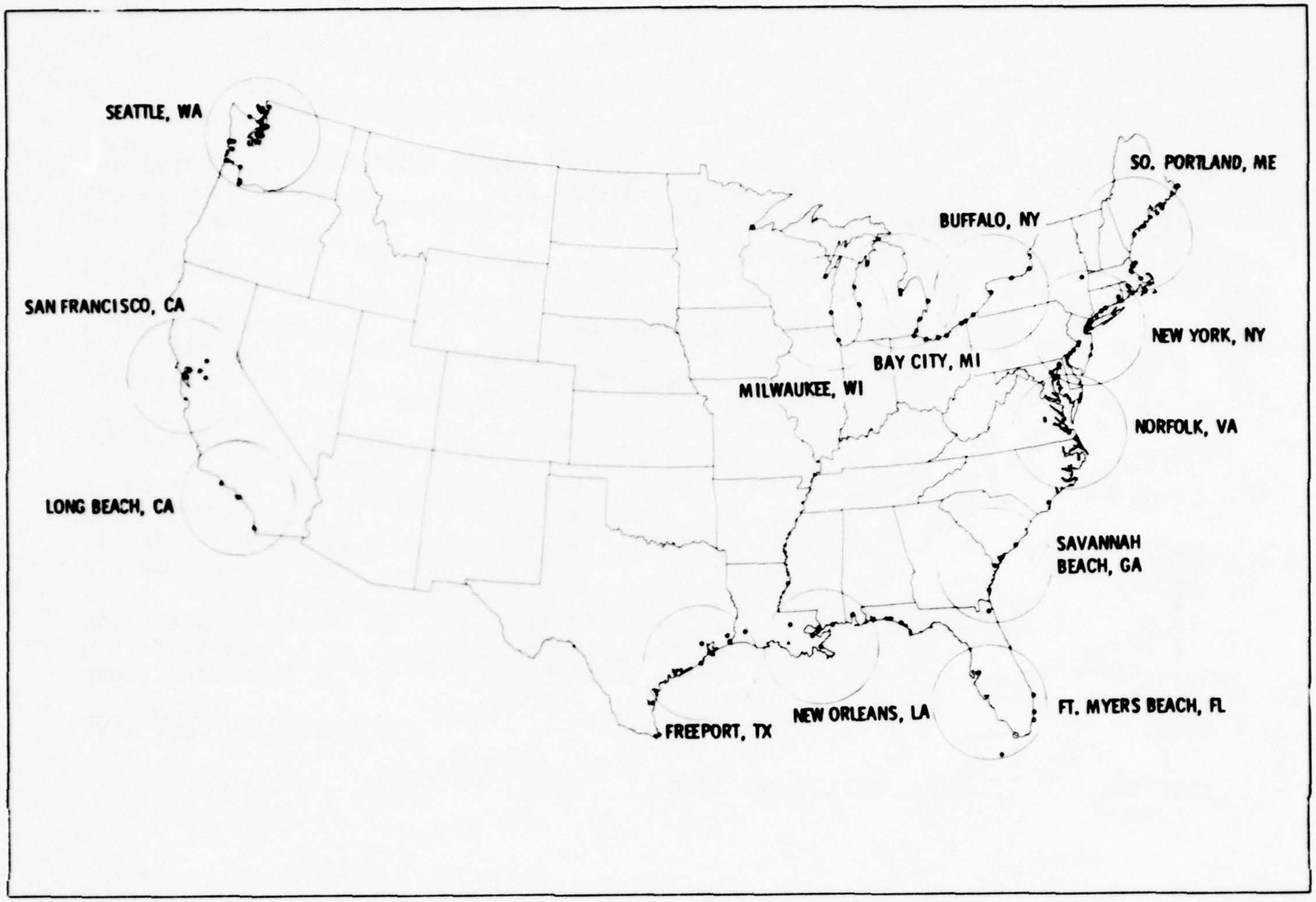

FIGURE 8-3. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION B

The list of sites in Configuration C is given in Table 8-4. The sites are plotted in Figure 8-4.

Configuration D: 11-Site Coverage

The number of sites was restricted to 11 in this configuration, allotted as follows:

2 on the Northeast Atlantic Coast

2 on the Southeast Atlantic Coast

2 on the Gulf Coast

3 on the Pacific Coast

2 in the Great Lakes Region

This allotment is somewhat arbitrary, being based on relaxing the 6-hour response requirement for certain low oil traffic density coastal areas: Northern Maine, Lake Ontario, and Lake Superior. It also provides only marginal coverage for the Wilmington, NC area, northern Lake Michigan, and upper Lake Huron. Finally, it provides double coverage for the New York and Jersey City areas, but at the limit of the 6-hour criterion.

The configuration is shown in Figure 8-5 and the sites are listed in Table 8-5.

The Providence, RI location has logistic advantages over Newport, RI and Narrangansett, RI, both of which are close to it. The advantage of Providence is proximity to I-95, which connects with Portland ME and New York, NY. The physical facilities at MSO Providence, however, may not be able to handle the required equipment, and one of the two alternates should then be employed.

The Savannah, GA location may be shifted to Charleston, SC, if necessary, affording better protection to Wilmington, NC rather than Jacksonville, FL.

The Great Lakes are covered, to an extent, by the Chicago site, which serves both sides of Lake Michigan, and the Cleveland site which must serve Lake Erie and Lake Ontario as well as the lower part of Lake Huron.

TABLE 8-4. SITE CONFIGURATION C

LOCATION	USCG FACILITIES	USCG DISTRICT
<u>EAST AND GULF COASTS</u>		
South Portland, ME	Base, Group Office	1
New York, NY	Station, COTP, Group Office	3
Baltimore, MD	Station, MSO, Yard, Group Office	5
Norfolk/Portsmouth, VA	Station, Base, MSO, Support Center, Group Office	5
Savannah Beach, GA	Station	7
Ft. Myers Beach, FL	Station	7
New Orleans, LA	Station, Base	8
Freeport, TX	Station	8
<u>GREAT LAKES</u>		
Sackets Harbor, NY*	Station	9
Erie, PA	Station, MSO	9
Bay City, MI	Station	9
Milwaukee, WI	Base, Station, COTP, Group Office	9
<u>WEST COAST</u>		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

*See footnote (*) on Table 6.1.

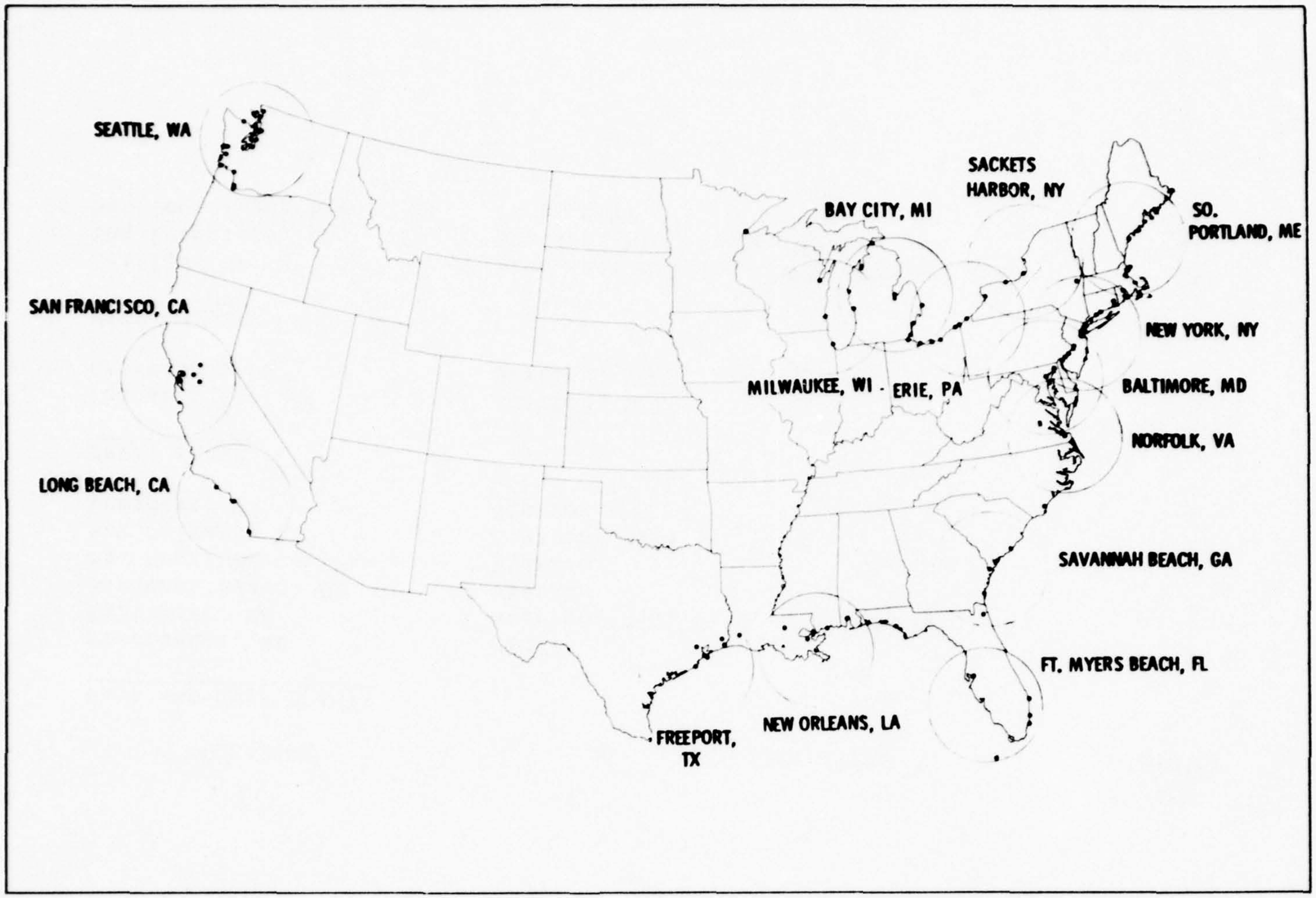

FIGURE 8-4. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION C

TABLE 8-5. SITE CONFIGURATION D

LOCATION	USCG FACILITIES	USCG DISTRICT
EAST AND GULF COASTS		
Providence, RI	MSO	1
Baltimore, MD	Station, MSO, Yard, Group Office	5
Savannah Beach, GA	Station	7
Ft. Myers Beach, FL	Station	7
New Orleans, LA	Station, Base	8
Freeport, TX	Station	8
GREAT LAKES		
Chicago, IL	Station, COTP	9
Cleveland, OH	Station, MSO	9
WEST COAST		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

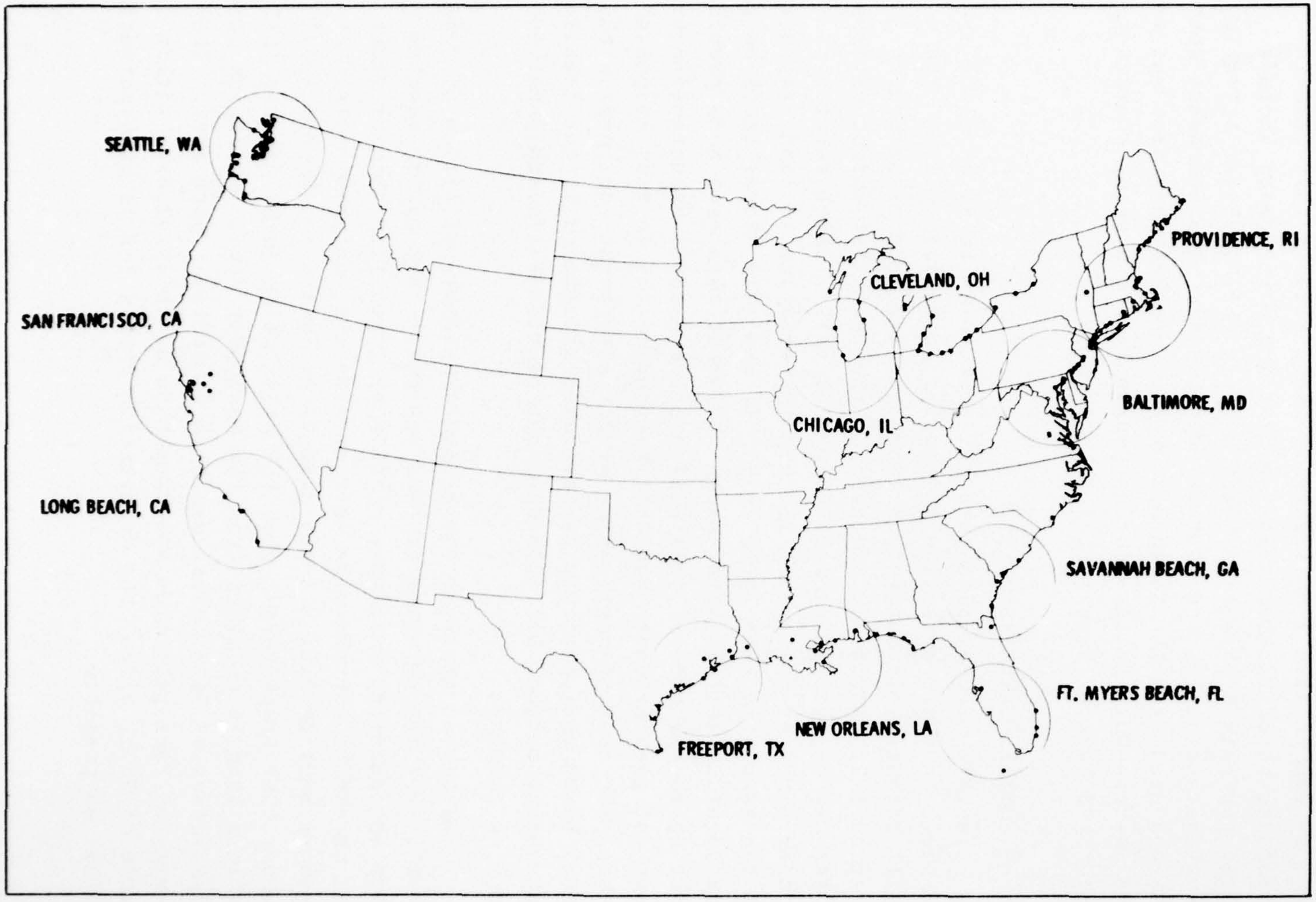

FIGURE 8-5. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION D

It can be seen from Figure 8-5 more clearly than from the preceding three figures that the East and Gulf Coasts include three separate debarkation point areas: the Northeast Atlantic, Southeast Atlantic, and Western Gulf Coasts. The Southeast sector is separated from the Northeast by the Cape Hatteras area and from the western Gulf by the Florida panhandle, both being characterized by a lack of significant oil ports.

8.3.2 Spill Potential Method

In this method, sites are selected so as to be as close as possible to the debarkation points for potential spills. The spill potential is determined from the data base described in Section 8.1. Advantage is taken of the fact that direct waterborne sites may be located at most major oil ports, which reduces response times by 30 to over 150 minutes relative to land transport at the same site (see Table 7-7). If the site stores truck-based equipment as well as water-based equipment then each mode provides back up to the other. This will provide greater amounts of equipment (at greater cost) but will not reduce the initial response time. The cost of duplicating direct waterborne equipment with truck-based equipment may be partially alleviated by the Transfer Waterborne option, but this does not provide extra equipment for back up response.

The key to applying the method is proper definition of "oil port". For the purposes at hand any point that may be reached from an equipment site more quickly by towed sled than by truck is, in effect, in the same port area as the equipment site. As seen in Section 7.5, a towed sled is estimated to reach a spill sooner than truck/vessel when the debarkation point for the spill is less than 36 n. miles from the equipment site. Hence, an effective radius of 36 n. miles was used to define a port area. The center of each port area was chosen so as to encompass, within a range of 36 n. miles, the debarkation points for as many potential spills as possible.

There are several measures of spill potential, given spill rates and oil flows. One may apply the spill rates to crude oil flows only, to heavy oil flows only, to light oil flows only, or to all types aggregated. Further, one may employ only coastal, foreign and Great Lakes oil movements (representing the potential for open water spills) or one may add to these the internal and local oil movements (the total representing the potential for harbor spills). In applying this method only heavy and crude oil movement was considered since the lighter oils present much less opportunity for pollution response. Further, the total of domestic and foreign oil movements was employed so that site selection would be based on both open water and harbor spill potential, it being considered impractical to segregate equipment sites on that basis. With the above choices for spill potential measures, the major "oil ports" within the study area were ranked in order of descending spill rate, as given in Table 8-6. It will be noted that OCS sites are included under their nearest debarkation point. Some ports show zero spill potential, based on heavy and crude flows, but are included to show the geographic extent of the port area. Some have substantial flows of light oils.

San Juan, Puerto Rico, and Barbers Point, Hawaii, have been included to show their spill potential and that of the surrounding harbors. In many cases, however, these surrounding harbors are more than 36 n. miles away.

Finally, it should be noted that the spill potentials of the Puget Sound port areas of Seattle and Anacortes have been adjusted for future Alaskan crude flows, as described above.

Figure 8-6 shows the cumulative value of expected spills/year over 50,000 gallons when the major oil port areas of Table 8-6 are taken in descending order. The total spill potential for all ports in the data base is 22.9 while the 26 major ports shown in Table 8-6 together account for 21.2 potential spills/year, or 92.5% of all potential spills. Twenty-one port areas alone account for 90% of all spill threat. These data, it will be recalled from Section 8.1, have been adjusted to 1985 for DWP's, trade shifts, OCS production, transient tankers and lightering.

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL*

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
PHILADELPHIA, PA	5.0671
Delaware River, Trenton NJ to the sea..................	5.0049
Wilmington Harbor, Delaware............................	0.0622
NEW ORLEANS, LA	2.7052
Port of New Orleans LA.................................	2.4158
Bay Marchand Blk2 2905,9101 (New Orleans)...............	0.0408
Eugene Island Blk330 2840,9142 (New Orleans)...........	0.0575
Eugene Island Blk276 2849,9133 (New Orleans)...........	0.0056
Grand Island Blk16 2905,8955 (New Orleans).............	0.0148
Grand Island Blk43 2900,8950 (New Orleans).............	0.0278
Main Pass Blk41 2925,8900 (New Orleans)................	0.0019
Main Pass Blk69 2915,8905 (New Orleans)................	0.0093
Ship Shoal Blk207 2832,9105 (New Orleans)..............	0.0111
South Pass Blk24 2900,8920 (New Orleans)...............	0.0204
South Pass Blk27 2855,8925 (New Orleans)...............	0.0111
South Pass Blk62 2900,8900 (New Orleans)...............	0.0074
South Pass Blk65 2900,8900 (New Orleans)...............	0.0130
Timbalier Bay Blk21 2901,9016 (New Orleans)............	0.0037
West Delta Blk30 2910,8936 (New Orleans)...............	0.0316
West Delta Blk73 2855,8945 (New Orleans)...............	0.0186
West Delta Blk58 2900,8950 (New Orleans)...............	0.0148
NEW YORK HARBOR	1.7862
Stamford Harbor CT.....................................	0.0010
Port of New York (Consolidated Statement)..............	1.6325
Hempstead Harbor NY....................................	0.0061
Glen Cove Creek NY.....................................	0.0000
Huntington Harbor NY...................................	0.0000
Jones Inlet NY...	0.0000
Sheepshead Bay NY......................................	0.0000
Oyster Bay NY..	0.0002

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
Baltimore Canyon Trough 2920,7239 (New York DBKPT)......	0.0366
Baltimore Canyon Trough 3916 (New York DBKPT)...........	0.0366
Baltimore Canyon Trough 3907,7223 (New York DBKPT)......	0.0366
Baltimore Canyon Trough 3845,7250 (New York DBKPT)......	0.0366
LOS ANGELES, CA	1.1889
Long Beach Harbor CA....................................	0.5438
Los Angeles Harbor CA...................................	0.5213
Huntington Beach 3340,11805 (Long Beach)................	0.0178
Wilmington 3346,11811 (Long Beach)......................	0.0906
Santa Barbara Island 3330,11905 (Los Angeles)...........	0.0154
RICHMOND, CA	1.1502
San Francisco Harbor CA.................................	0.0125
Redwood City Harbor CA..................................	0.0000
Oakland Harbor CA.......................................	0.0324
Richmond Harbor CA......................................	0.4722
San Pablo Bay and Marie Island Strait CA................	0.1282
Carquinez Strait CA (Benicia, Martinez).................	0.3619
Suisun Bay Channel CA (Pittsburg, Antioch)..............	0.0399
Other San Francisco Bay Area Ports CA (Estero Bay)......	0.1031
PASCAGOULA, MS	1.1205
Mobile Harbor AL..	0.3477
Pascagoula Harbor MS....................................	0.7642
Biloxi Harbor MS..	0.0035
Gulfport Harbor MS......................................	0.0006
Eastern Gulf of Mexico 3000,8730 (Mobile AL)............	0.0008
Eastern Gulf of Mexico 2935,8715 (Mobile AL)............	0.0008
Eastern Gulf of Mexico 2915,8750 (Mobile AL)............	0.0008
Eastern Gulf of Mexico 2918,8610 (Mobile AL)............	0.0008
Eastern Gulf of Mexico 2830,8545 (Mobile AL)............	0.0008
BATON ROUGE, LA	1.0660

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
TEXAS CITY, TX	1.0250
Houston Ship Channel TX................................	0.6502
Texas City Channel TX................................	0.2711
Galveston Channel TX................................	0.0047
Freeport Harbor TX................................	0.0990
PORT ARTHUR, TX	0.8801
Sabine-Neches Waterway, Beaumont, Orange, Port Arthur...	0.8801
CORPUS CHRISTI, TX	0.7417
PORTLAND, ME	0.6551
SEATTLE, WA	0.5606
Hammersley Inlet WA................................	0.0000
Tacoma Harbor WA................................	0.1150
Seattle Harbor WA................................	0.0794
Everett Harbor and Snohomish River WA..................	0.0081
Other Puget Sound Area Ports WA........................	0.3580
LAKE CHARLES, LA	0.4160
Calcasieu River and Pass................................	0.4160
HAMPTON ROADS, VA	0.4064
Hampton Roads VA (Includes Newport News, Norfolk).......	0.3021
Little River Creek VA (Includes Virginia Beach VA)......	0.0000
York River VA (NR Williamsburg VA)....................	0.1043
ANACORTES, WA	0.3286
Port Townsend Harbor WA................................	0.0010
Anacortes Harbor WA................................	0.3120
Bellingham Bay and Harbor WA...........................	0.0156

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
BOSTON, MA	0.3006
Salem Harbor MA	0.0433
Port of Boston MA	0.2460
Plymouth Harbor MA	0.0113
Beverly Harbor MA	0.0000
Glocester Harbor MA	0.0000
CHICAGO, IL	0.2751
Port of Chicago IL	0.1423
Indiana Harbor IN	0.1328
BALTIMORE, MD	0.2708
Baltimore Harbor and Channels MD	0.2352
Washington Harbor DC	0.0349
Annapolis Harbor MD	0.0006
Chester River MD	0.0001
Middle River and Dark Head Creek MD	0.0000
Susquehanna River above and below Havre de Grace	0.0000
ALBANY, NY	0.2484
Hudson River, Upper Bay in NY Harbor to Waterford NY	0.2484
JACKSONVILLE, FL	0.2458
St. Marys River GA and FL	0.0059
Fernandina Harbor FL	0.0105
Jacksonville Harbor FL	0.1747
Rice Creek FL	0.0058
Southeast Georgia Embayment 3045,8030	0.0163
Southeast Georgia Embayment 3025,8035	0.0163
Southeast Georgia Embayment 3029,8018	0.0163

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
BARBERS POINT, HI	0.1859
Hilo Harbor HI	0.0035
Kawaihae Harbor HI	0.0000
Kahului Harbor HI	0.0041
Barbers Point Harbor HI	0.1657
Honolulu Harbor HI	0.0116
Nawiliwili Harbor HI	0.0001
Kaunakakai Harbor HI	0.0000
Port Allen Harbor HI	0.0009
PORT EVERGLADES, FL	0.1502
Port Everglades Harbor FL	0.0888
Miami Harbor FL	0.0614
NEW HAVEN, CT	0.1452
Connecticut River below Hartford CT	0.0227
New Haven Harbor CT	0.0621
Bridgeport Harbor CT	0.0368
Norwalk Harbor CT	0.0103
Westport Harbor and Saugatuck River CT	0.0000
Port Jefferson Harbor NY	0.0133
Great South Bay NY (Patchogue NY)	0.0000
Sag Harbor NY	0.0000
PROVIDENCE, RI	0.1188
Fall River Harbor MA	0.0657
Providence River and Harbor RI	0.0483
Seekonk River RI	0.0003
Warren River RI	0.0000
Cuttyhunk Harbor MA	0.0000
New Bedford and Fairhaven Harbor MA	0.0030
Newport Harbor RI	0.0015

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
SAN JUAN, PR	0.0939
San Juan Harbor PR	0.0823
Ponce Harbor PR	0.0006
Mayaguez Harbor PR	0.0001
St. Thomas Harbor VI	0.0031
Christiansted Harbor VI	0.0078
Fajardo Harbor PR	0.0000
TAMPA, FL	0.0885
St. Petersburg Harbor FL	0.0057
Tampa Harbor FL	0.0325
Weedon Island FL	0.0431
Eastern Gulf of Mexico 2840,8325 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2724,8405 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2705,8415 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2715,8355 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2705,8335 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2645,8326 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2642,8405 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2612,8410 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2610,8326 (Tampa FL)	0.0008

*Based on crude and heavy oil flows and spills larger than 50,000 gallons from 1974-77, adjusted to 1985. The values of SPILLS/YR. are shown to four decimal places only to facilitate ranking; their accuracy is no better than two decimal places.

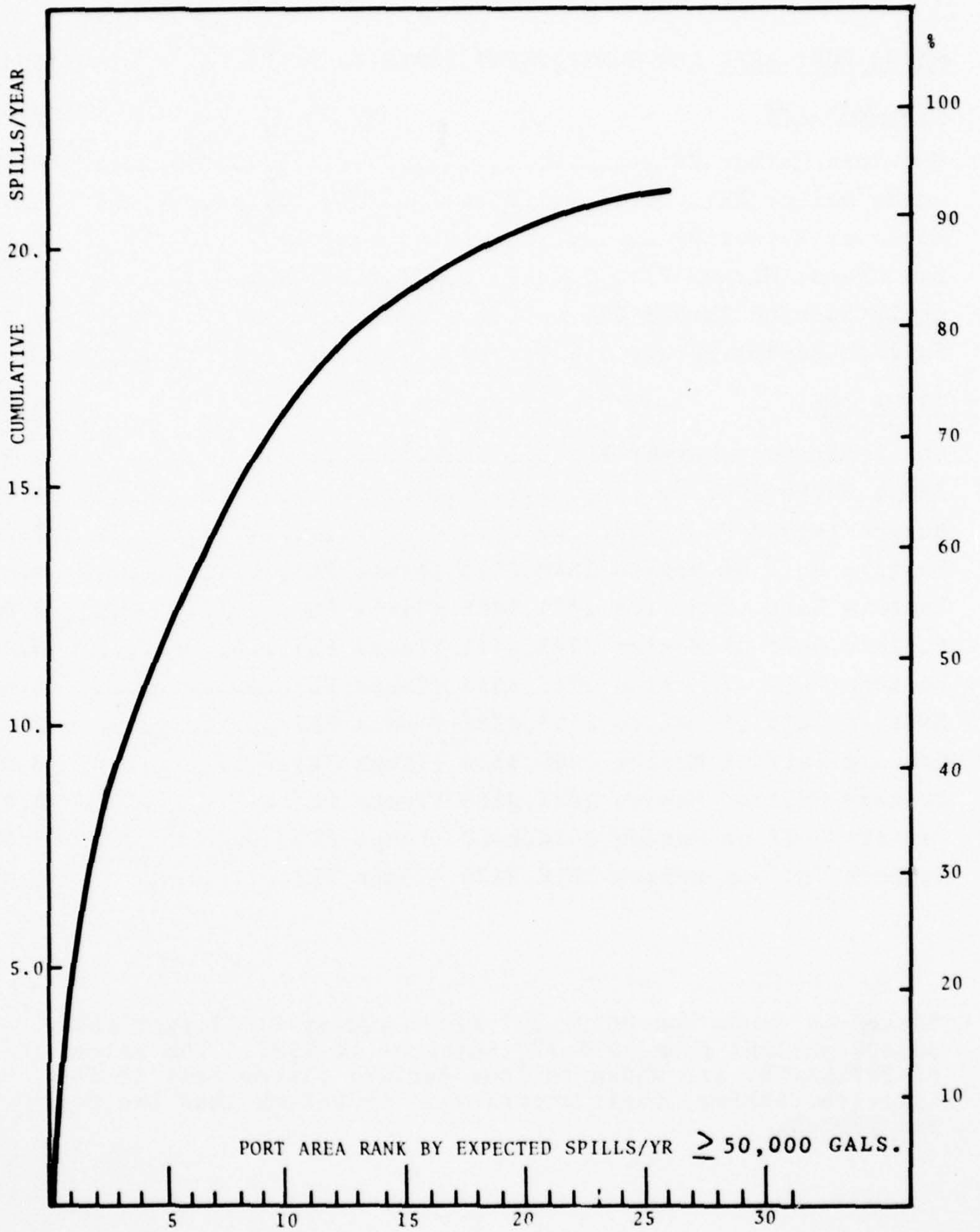

FIGURE 8-6. CUMULATIVE SPILL THREAT FOR 26 U.S. PORT AREAS

Configuration 1: 17 Sites

Since it appears that good land coverage can be achieved with 17 sites, a configuration based on this number, plus one each for Hawaii and Puerto Rico, was constructed using the second site-selection criterion. If the top 17 sites of Table 8-6 were selected, however, the result would be seven sites in the Louisiana-Texas area, non in the Georgia-Alabama-Florida area, and only one in the Great Lakes. Furthermore, the two New England sites (Boston, Portland) would be in close proximity.

To remedy the apparent deficiencies of straight ordering, the Baton Rouge site was eliminated because of its proximity to New Orleans, and one in Florida substituted. Of the three possible sites in Florida (Jacksonville, Tampa, Port Everglades) Tampa was selected because of its central location. Next, the Lake Charles site was eliminated because of its proximity to Port Arthur, and a Great Lakes site substituted. This was chosen to be Buffalo NY in order to cover both lake Erie (along with the Chicago site) and Lake Ontario. Finally the Boston site was moved to Providence RI to cover Woods Hole and the Georges Bank area.

The resulting configuration is shown in Table 8-7, and plotted in Figure 8-7. The smaller circles in the Figure show the effective range of Direct Waterborne. In associating oil ports with USCG installations some adjustments in location were made:

1. Hampton Roads was taken as Portsmouth/Norfolk, VA. The USCG and Navy installations in this area are numerous, have large capacity, and excellent access to Chesapeake Bay and the Atlantic Ocean. They also cover the Hampton Roads and York River approaches.

2. Clearwater FL was substituted for Tampa, because of the large storage facilities and air base. It is nevertheless desirable to use Tampa for direct water coverage of Tampa Bay, if a water location can be found. The Tampa direct water site, how ever, is not essential.

TABLE 8-7 SITE CONFIGURATION 1

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Portland, ME	Base, Group Office	L,DW*
Providence, RI	MSO	L,DW
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
Pascagoula, MS	Station	DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Port Aransas, TX	Station, Group Office	DW
WEST COAST		
San Pedro, Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office	DW
Bellingham, WA	Station	
GREAT LAKES		
Chicago, IL	Station, COTP	L
Buffalo, NY	Base, MSO, Group Office	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode Land
DW = Direct Waterborne.

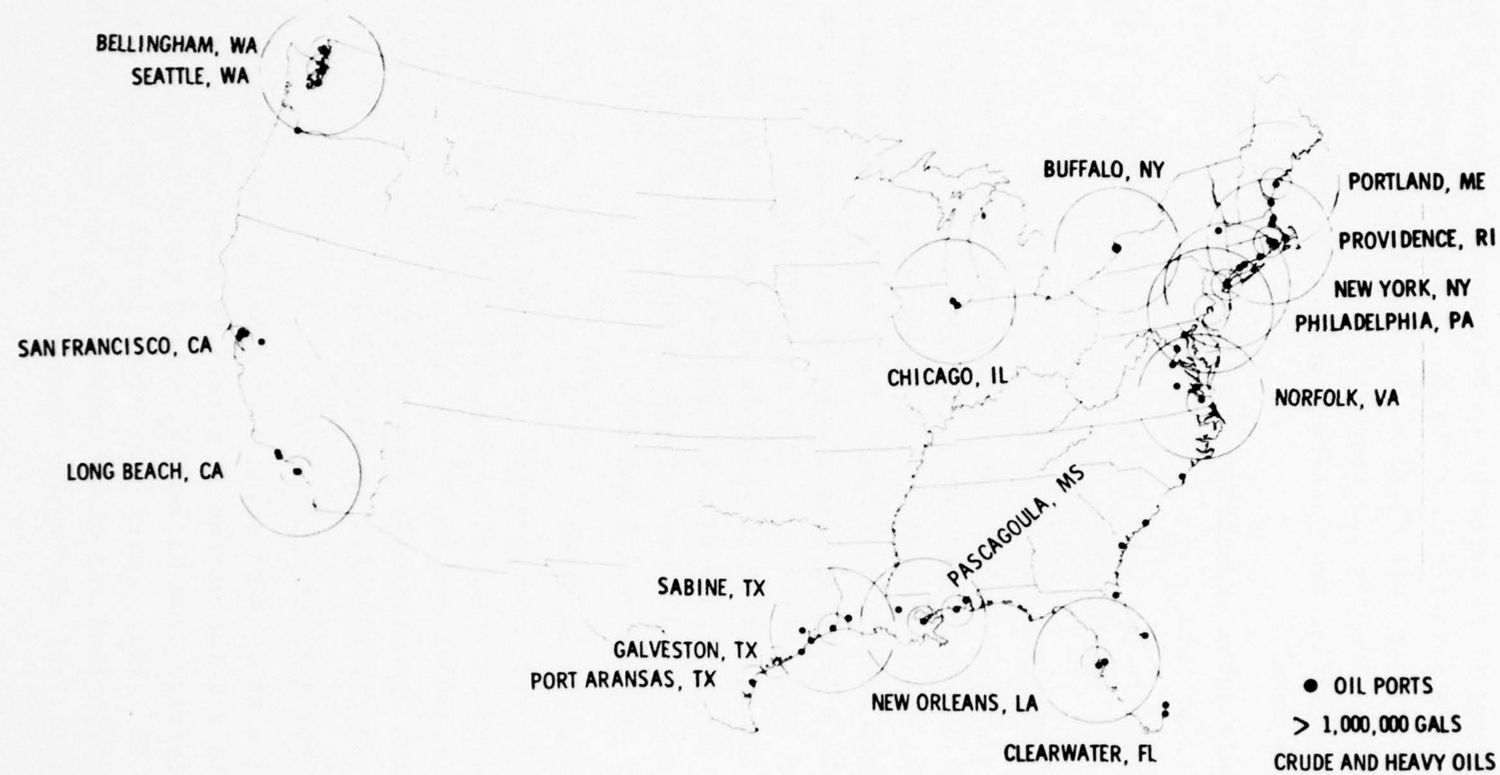

FIGURE 8-7. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 1).

3. Sabine TX is superior to Port Arthur because it has a more rapid access to the Gulf Coast. A land transport capability at Sabine can serve Lake Charles, and supplement direct water capability at Galveston and Corpus Christi. The direct water capability at Sabine provides back-up for its land delivery to the Lake Charles area.

4. Bellingham was substituted for Anacortes, which has no USCG station or base.

5. Honolulu was substituted for Barber's Point. Either site may be used as discussed in Section 8.5.

Configurations 2 and 2a: 15 Sites

Reduction to 15 sites was achieved by consolidating the Portland ME and Providence RI sites into a land and water site at Boston. The Bellingham WA site was eliminated, because of truck coverage from Seattle. If Puget Sound traffic should increase however, the Bellingham site should be substituted for the Buffalo site, so as to maintain a 15 site configuration. This is the basis for Configuration 3, which is the same as Configuration 2 except for the presence of Bellingham WA instead of Buffalo NY. Configurations 2 and 2a are listed in Tables 8-8 and 8-9, and illustrated in Figures 8-8 and 8-9.

Configuration 3: 13 Sites

If a 13-site configuration is assumed then Configuration 2 may be reduced by eliminating the Buffalo site (without replacement by Bellingham) and the Pascagoula site (which is about 100 n. miles from New Orleans). The resulting site list is shown in Table 8-10 and illustrated in Figure 8-10.

Configurations 4 and 4a: 11 Sites

The 11-site configuration is reached by eliminating the Chicago site and the Sabine TX site. To compensate for the loss of truck coverage from Sabine TX, a land capability is added to Galveston, TX. This leaves four sites in the Gulf area, three of which have both land and water capability, and one of which, Corpus Christi, has only water capability.

TABLE 8-8. SITE CONFIGURATION 2

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air base	L,DW
Pascagoula, MS	Station	DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro/Long Beach CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COPT, Large Air Station, Group Office, Support Center	L,DW
GREAT LAKES		
Chicago, IL	Station, COTP	L
Buffalo, NY	Base, MSO, Group Office	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

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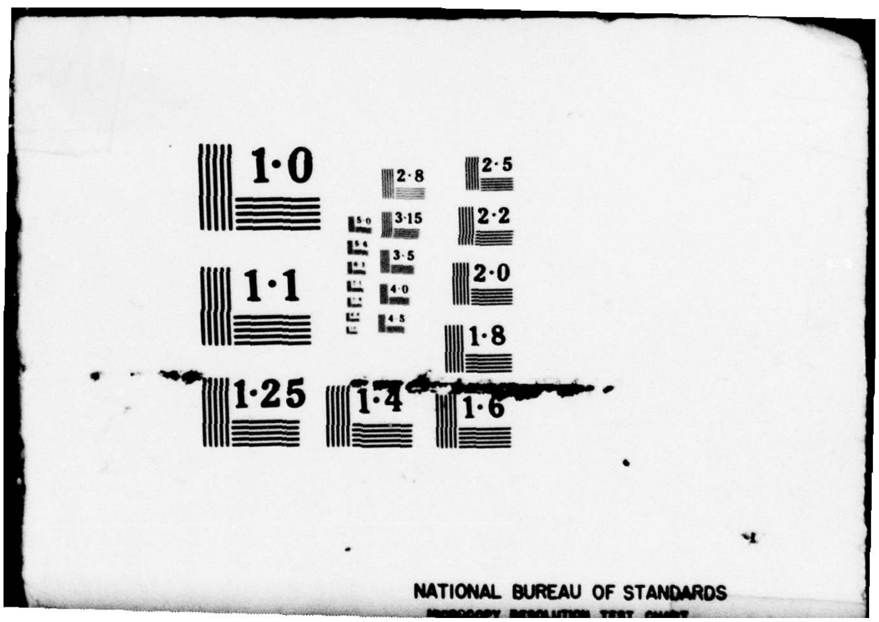
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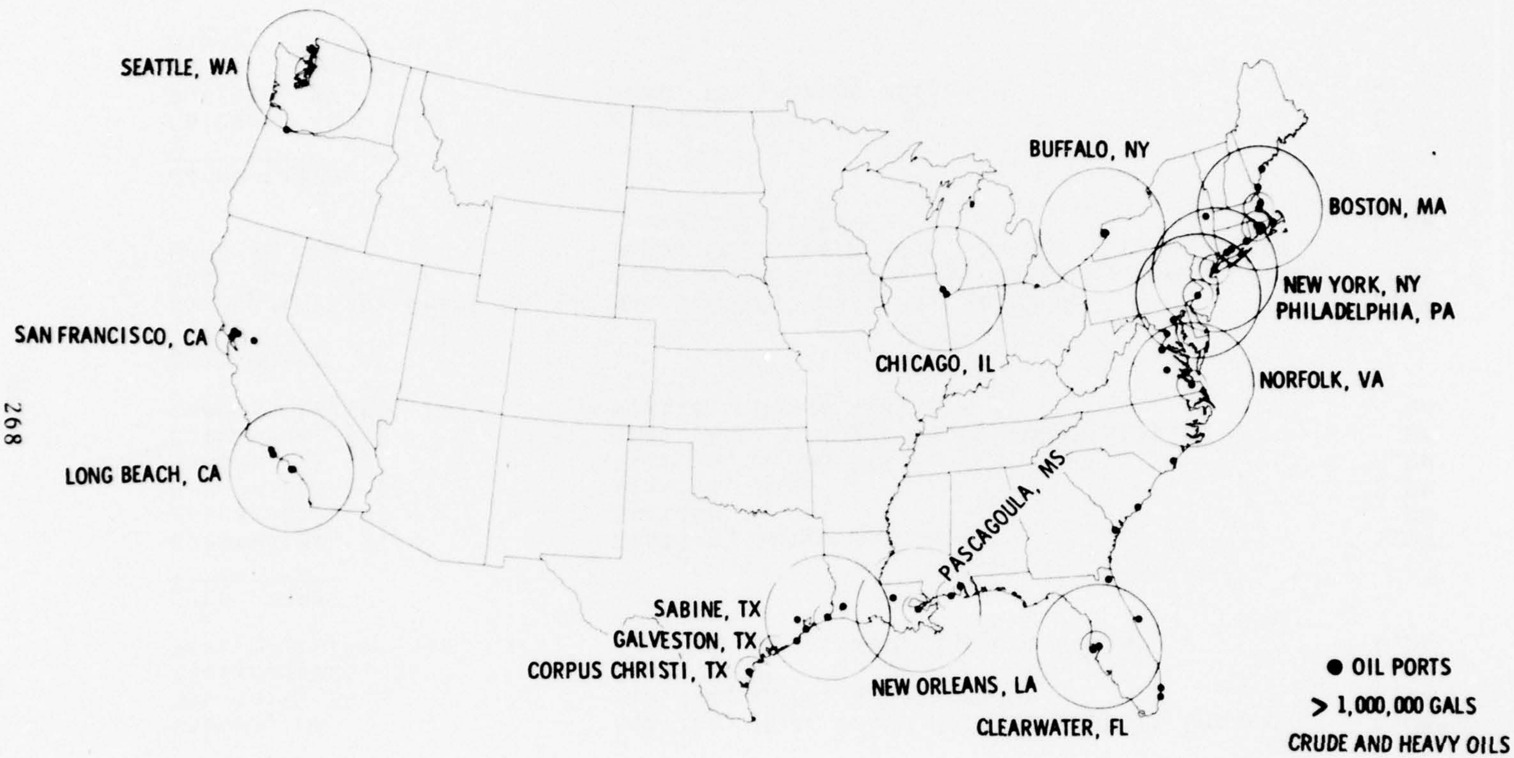


FIGURE 8-8. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 2).

TABLE 8-9. SITE CONFIGURATION 2a

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfold, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
Pascagoula, MS	Station	DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro, Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
Bellingham, WA	Station	DW
GREAT LAKES		
Chicago, IL	Station, COTP	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

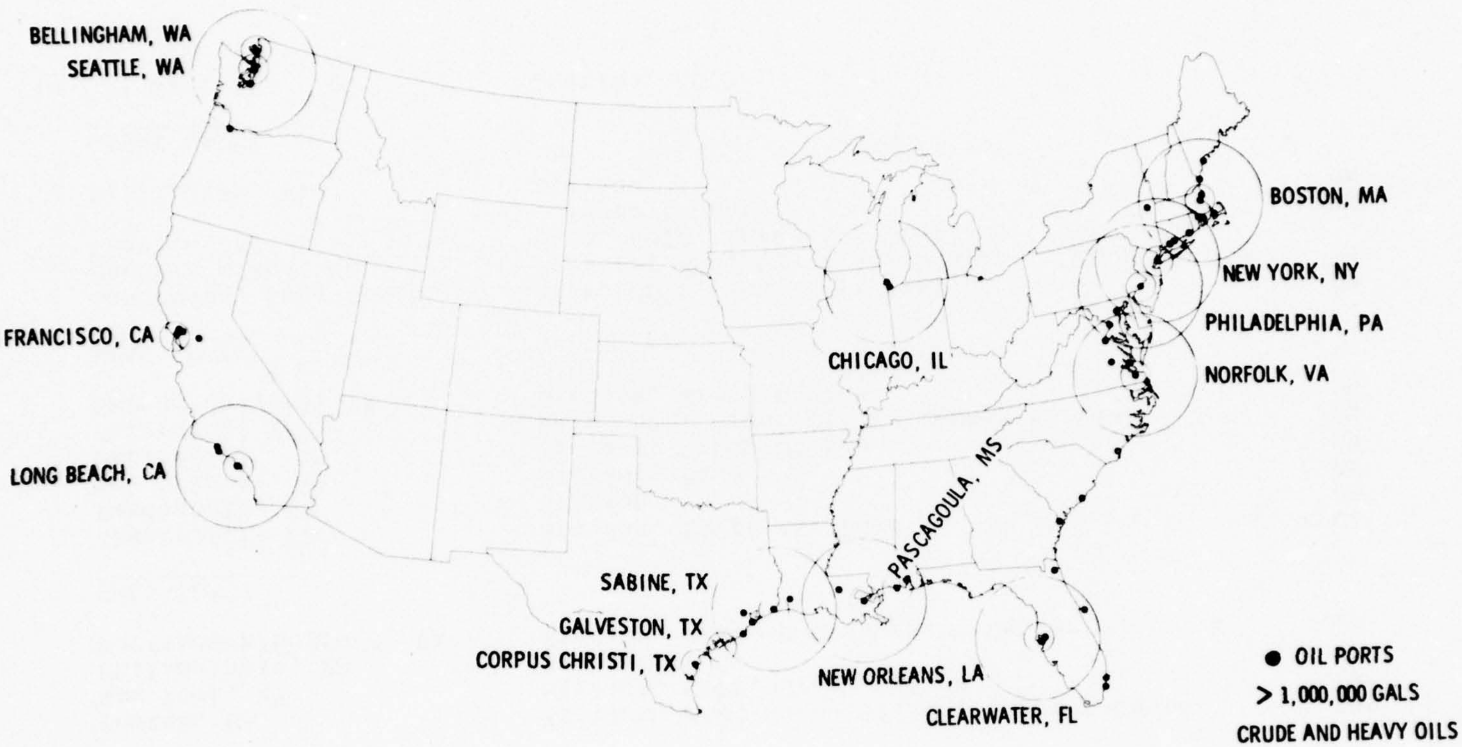


FIGURE 8-9. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 2A).

TABLE 8-10. SITE CONFIGURATION 3.

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro, Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
GREAT LAKES		
Chicago, IL	Station, COTP	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode Land
DW = Direct Waterborne

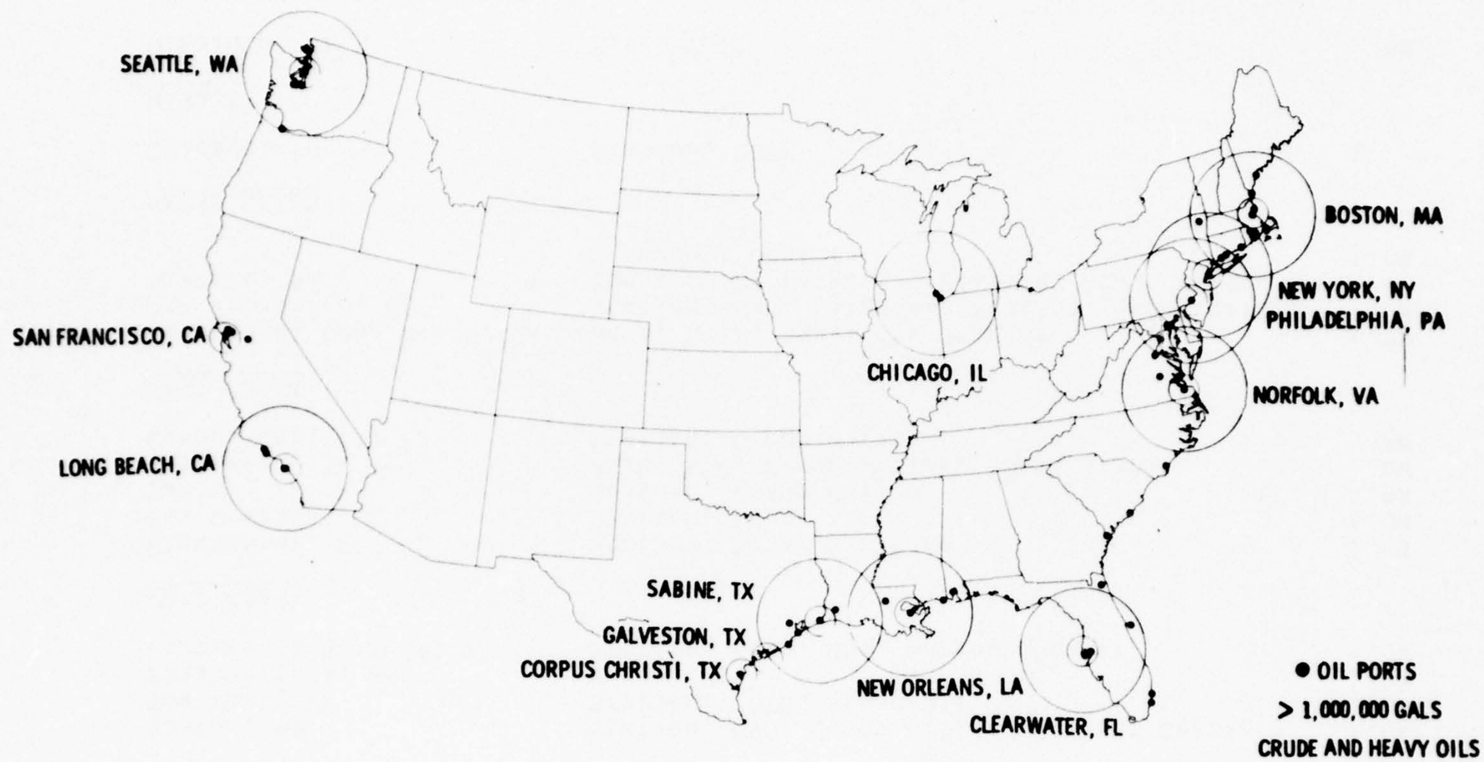


FIGURE 8-10. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 3).

TABLE 8-11. SITE CONFIGURATION 4

LOCATION	USCG FACILITIES	TYPE
EAST COAST		L,DW*
Boston, MA	Station, MSO, Group Office, Support Center	L,DW
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
New Orleans, LA	Station, Base	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	L,DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro/Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
GREAT LAKES		
None	-	-
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

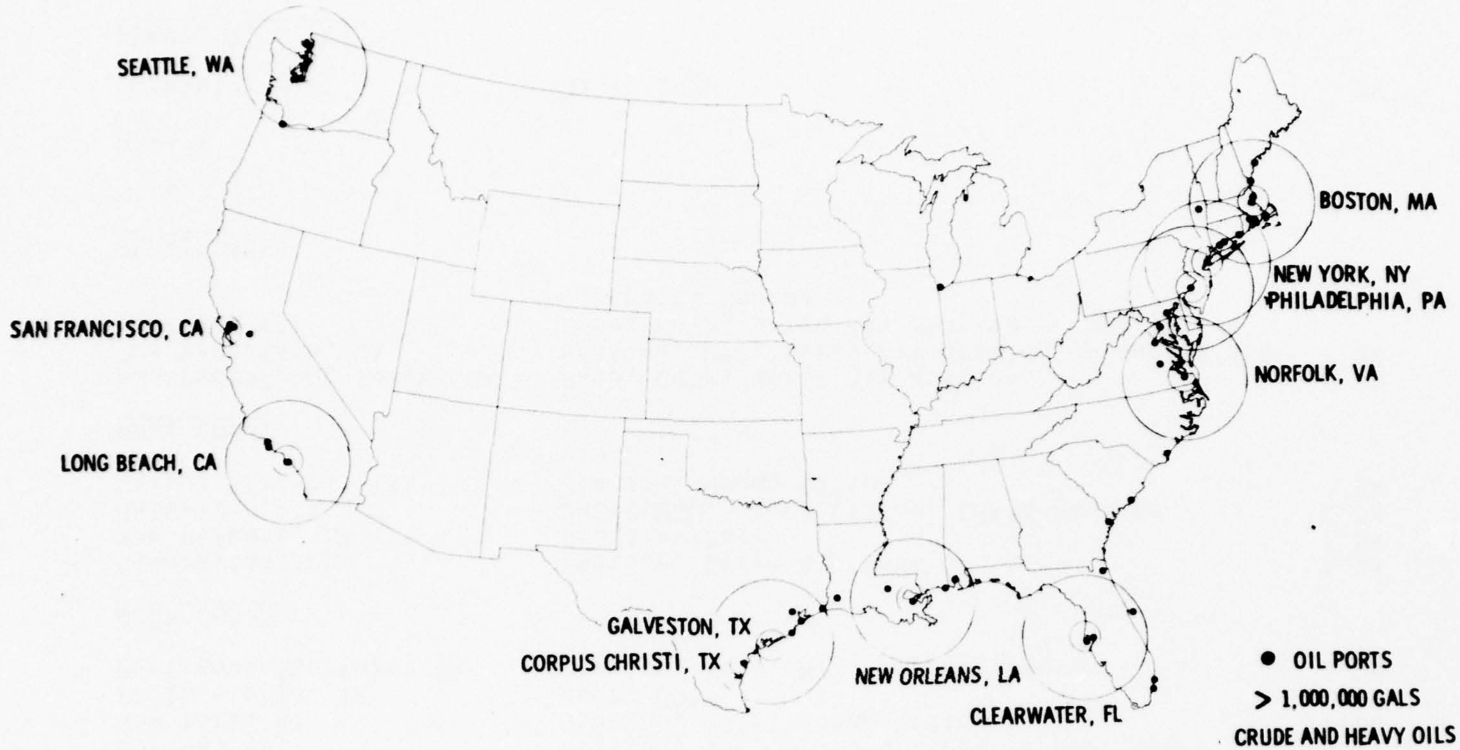


FIGURE 8-11. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 4).

The sites of Configuration 4 are listed in Table 8-11 and shown in Figure 8-11.

Since an 11-site configuration is likely to have poor coverage within six hours of the Great Lakes, Lower East Coast, parts of New England, and the West Coast, it was conjectured that one or more air sites, colocated with some of the 11 sites, would improve response times. Since the air speeds are comparatively large (average of 295 kts for C130H and C130B), the location of an air base in not critical. A single air site was located at Clearwater FL in Configuration 4a. It may have also been placed at Elizabeth City, NC, Belle Chasse, LA or in the Los Angeles or San Francisco areas. Clearwater was chosen because (1) San Francisco or Los Angeles would not serve the East Coast as well, (2) Elizabeth City is not a site in Configuration 4, (3) Belle Chasse LA is not a site in Configuration 4, (4) Los Angeles is a small air station. The placement of an equipment site at Elizabeth City, NC however, would provide slightly better Great Lakes coverage than Clearwater, FL.

The sites of Configuration 4a are listed in Table 8-12

8.4 METHOD OF EVALUATING SITE CONFIGURATIONS

The most important measures of site configuration effectiveness are those extracted from the distribution of the response times, such as is illustrated in Figure 8-1. The measures selected are

1. Mean value of response time T

2. Fraction of responses in excess of 6 hours.

These are independent measures, within limits, as may easily be shown. Of the two, primary value will be placed on the first, since it is most closely related to spill recovery effectiveness. A third measure will also be applied, namely

3. Fraction of historic spills responded to within 6 hours.

TABLE 8-12. SITE CONFIGURATION 4a

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	A,L,DW
New Orleans, LA	Station, Base	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	L,DW
Port Aransas, TX	Station, Group Office	DW
WEST COAST		
San Pedro/Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
GREAT LAKES		
None	-	-
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

1. Average Response Time

This measure is simply the average of the distribution of response times T, such as shown in Figure 8-1. If in a one year period there are n_j spills in region j, with response times T_j from the nearest storage site, then the average response time $\overline{T}$ is:

$$\overline{T} = \sum_j T_j n_j \Big/ \sum_j n_j$$

where the summations are over all regions j. In actuality, the exact values of n_j are never known, but the average values $\overline{n}_j$ may be used since they were calculated from the spill rates of Section 3 and are available in the spill potential data base described previously.

The average response time, as above, was calculated for expected spills of crude and heavy oil, both coastal, foreign, inland, local and Great Lakes, throughout the study area, as contained in the spill potential data base. The average response time for each site as well as a national average was calculated. In addition, the frequency distribution of response times was tabluated for the entire study area for each configuration.

Since the candidate configurations include land and water modes, each potential spill location was assigned to either a land (L) or direct waterborne (DW) site, depending on which provided the shorter time T* from site to spill as given in Section 7.5. The equivalent response time T from storage site to debarkation point was then calculated, from the formulas in the same Section, in order to obtain the contribution of that spill potential to $\overline{T}$.

2. Percent of Response Times Greater Than 6 Hours

If the time to respond to each projected spill is analyzed into intervals of 0-1 hrs, 1-2 hrs, 2-3 hrs, etc., a histogram of response times may be obtained such as Figure 8-1. The fraction

of spills with response times greater than six hours is then an indicator of configuration performance. A configuration that shows zero spill responses greater than six hours has perfect performance with regard to that criterion, but may be poor in other performance measures, or from a practical point of view. Therefore, greater flexibility and better overall performance can be expected if attention is directed to configurations with a reasonably low, but not zero, percentage of spills with response times greater than 6 hours. A level of 5% will be employed in this study, making it possible to justify the statement that acceptable configurations meet the six hour criterion for 95% of the projected spills.

An alternate interpretation of the six-hour response measure is the fraction of potential debarkation ports beyond six hours response time from some site. This differs from the spill-fraction criterion just described because ports vary widely in their number of expected spills. The debarkation port criterion is more stringent than the spill criterion. It includes response times to many oil ports that carry only small amounts of barge traffic. Nevertheless, this subsidiary measure provides a valid performance indication, and will be tabulated. In calculating this criterion, however, the assumption must be made that any oil port may serve as a debarkation port for spills connected with its traffic. This is approximately true, since oil movement at the smaller ports is likely to involve smaller vessels, and smaller spills. Therefore, less pollution response equipment would be needed, and the port depths are likely to be adequate for pollution response vessels. In other words, the depth required by pollution response vessels is likely to be no greater than that required by the oil carriers using the port.

3. Percent of Historic Spills Encompassed

As a test of how well the candidate site would have performed in the years 1974-1977, the number of spills in the MOSIS data base that are within 6 hours response time of some site in the configuration may be counted and tabulated as a measure of performance of the configuration.

In determining whether a spill would have been covered by a configuration in six hours, it is necessary to assign to each spill a debarkation point, and then to determine if the debarkation points lie in the coverage area of one or more sites. Since we are interested primarily in open water spills, the 149 ports with crane or lift service are appropriate debarkation points, because they can handle the barrier and Type O barges.

Tabulation and Evaluation of Results

Table 8-13 shows the results of applying the three evaluation measures to the ten configurations A, B, C, D, 1, 2, 2a, 3, 4, and 4a previously devised. Examination of that Table shows the following:

All configurations derived by the spill potential method produced lower average response times than any produced by the debarkation point method. But the alpha configuratiuons were superior to the numeric configurations with regard to the 6-hour response criterion. It is clear, then, that each method produced results in accordance with its intent.

The distributions of response times (by spill, not by port) are plotted in Figures 8-12 and 8-13. In Figure 8-12 it is apparent that as the number of sites is reduced in the sequence A, C, B, D, the distribution moves to the 6-hour line, but does not cross it to any great extent. The same occurs in the 1, 2, 3, 4 sequences, in Figure 8-13, except that Configuration 4 exceeds the nominal 5% level set for response times greater than 6 hours. Configuration 4a, however, dramatically reduces the percent responses greater than 6 hours to 1.29%, due to the addition of air capability.

The Configuration with the lowest average response time is Configuration 1, as expected, because it involves the maximum number of sites. A measure of cost or resources expended should be introduced to account for the better results achieved with more sites. Simply counting the sites does not allow for the fact that at some sites both a land and a water capability are deployed.

TABLE 8-13. EVALUATION MEASURES FOR TEN SITE CONFIGURATIONS

CON-FIGUR-ATION	NUMBER OF SITES (1)	AVERAGE RESPONSE TIME	PERCENT > 6 HRS SPILLS	PERCENT > 6 HRS PORTS	HISTORIC SPILLS COVERED
A	17 + 2	3.61 HRS	1.53%	11.3%	98.8%
B	13 + 2	3.31	1.88	14.0	95.0
C	15 + 2	3.24	0.83	12.0	95.0
D	11 + 2	3.76	2.57	20.7	92.5
1	17 + 2	2.19	4.06	25.7	91.3
2	15 + 2	2.29	4.23	28.0	91.3
2a	15 + 2	2.29	4.40	29.7	87.5
3	13 + 2	2.43	4.55	30.3	87.5
4	11 + 2	2.64	5.17	35.3	86.3
4a	11 + 2	2.45	1.29	25.0	91.3

NOTES (1) Number of sites in the 48 states, plus one each for Puerto Rico and Hawaii.

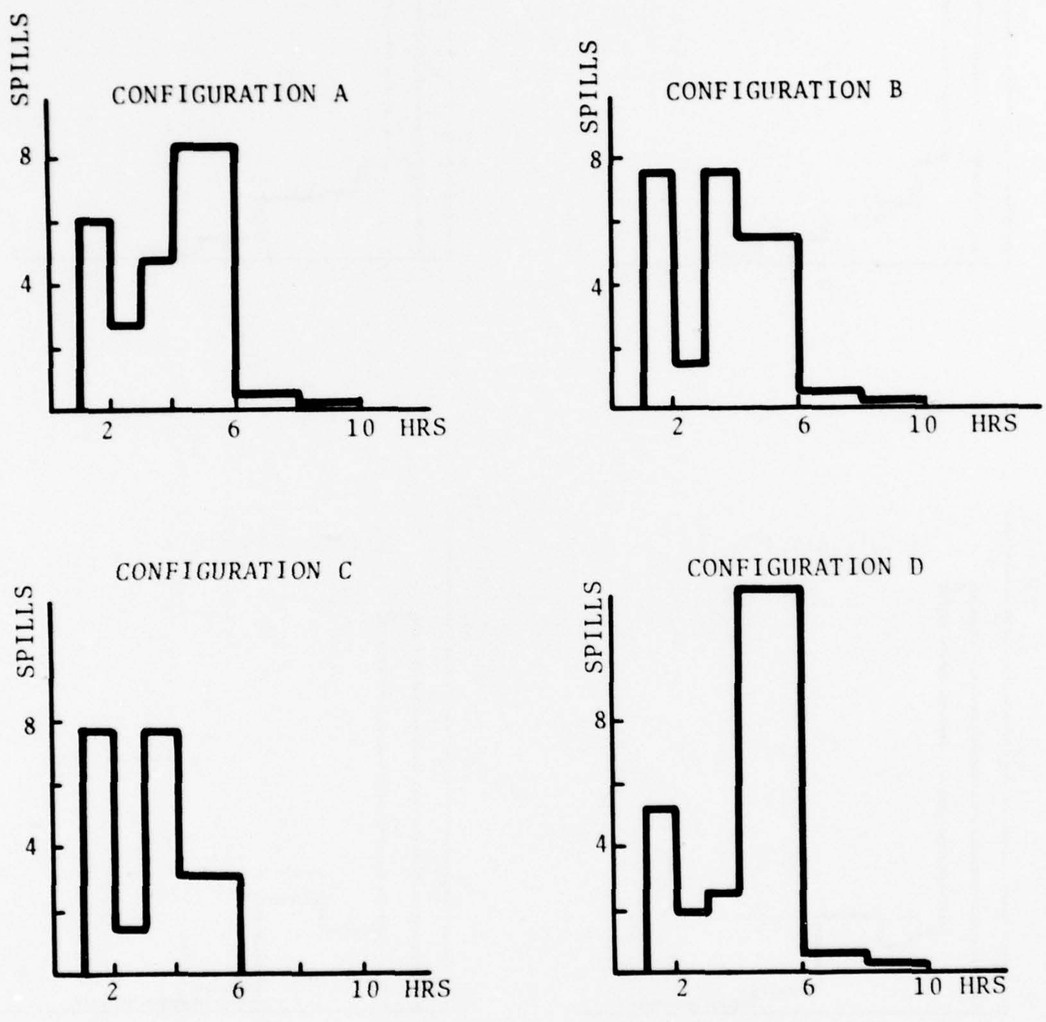


FIGURE 8-12. DISTRIBUTION OF RESPONSE TIMES FOR CONFIGURATIONS A, B, C, AND D

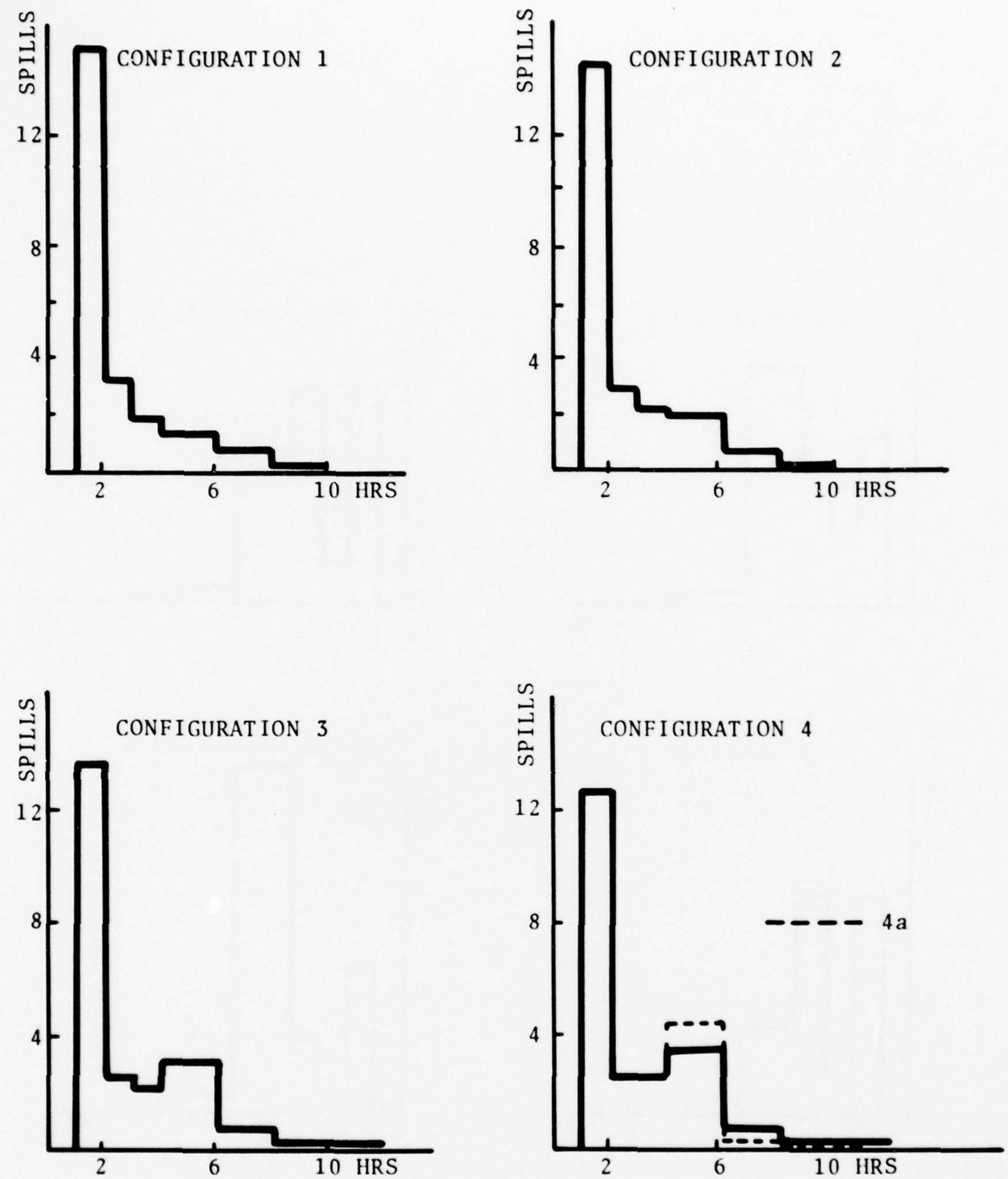


FIGURE 8-13. DISTRIBUTION OF RESPONSE TIMES FOR CONFIGURATIONS 1, 2, 3, 4, and 4a

A better measure is the number of separate capabilities deployed, counting each land and water capability separately in Tables 8-7-8-12. With this as an independent variable the average response time and percent of response times greater than 6 hours are plotted in Figure 8-14.

From Figure 8-14 is apparent that as more sites are added the average response time drops. Except for Configuration A, the drop is surprisingly smooth, which indicates that effectiveness is not an erratic function of capability. While the spill potential method of site selection produces a gradual improvement in response time, it also produces close to the nominal 5% tolerance on response times greater than 6 hours. The sharp drop in that measure due to the 4a air site is very apparent. It seems clear, then, that the addition of air sites to the 1, 2, 3, 4 configurations will markedly reduce the number of spill responses that take over six hours.

It should be noted that the asymptote for the response time curve of Figure 8-14 is about 1.77 hours, the value obtained with 30 sites, each having both land and water capability. This asymptote represents might be achieved by introducing direct waterborne capability to all sites.

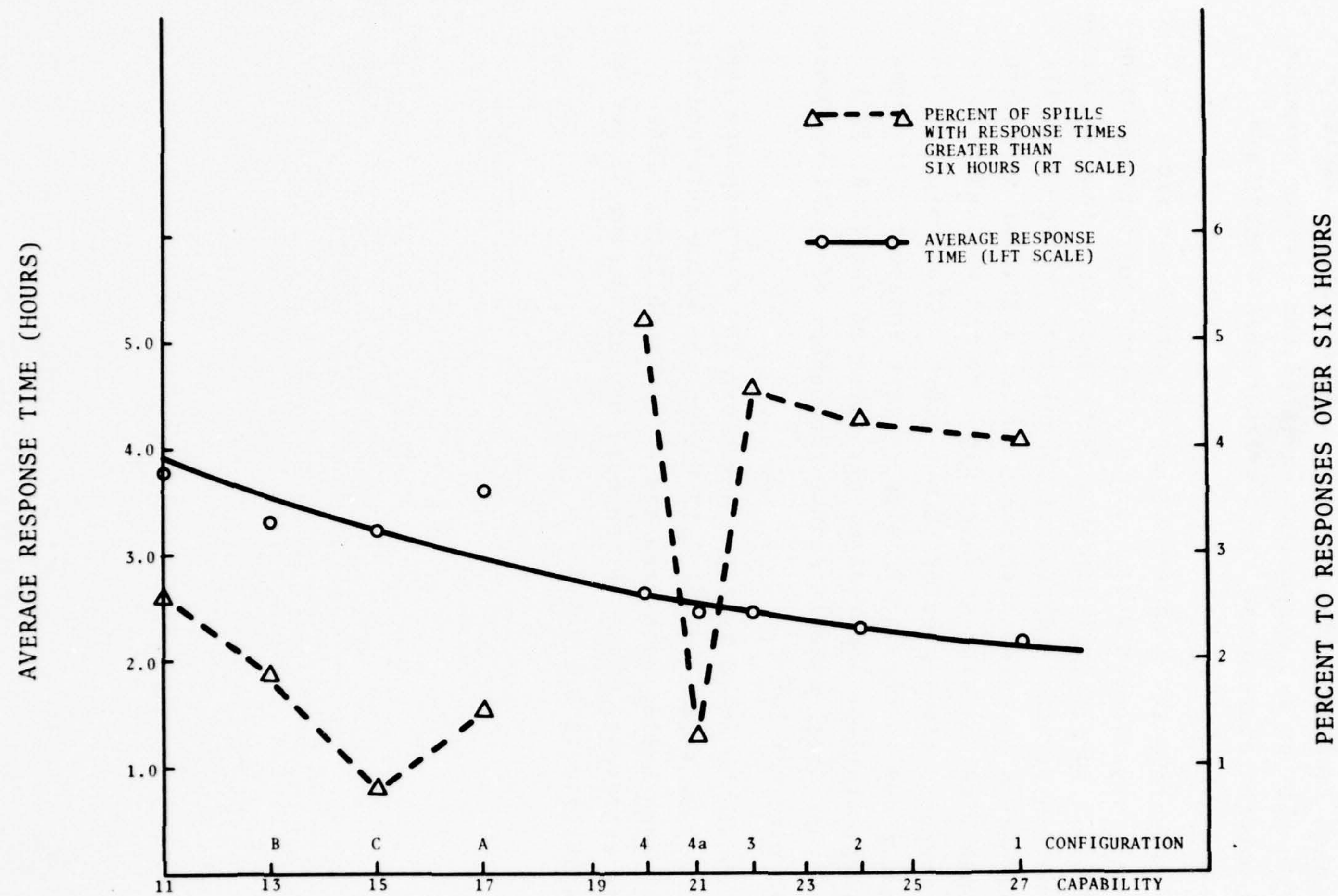


FIGURE 8-14. MEASURES VS CAPABILITY

8.5 SITE SELECTION

It is now possible to analyze the previous ten combinations and to select one, or a combination of several, that provides good average response time and also achieves about 95% of the spill responses in less than six hours. The analysis consists of examining for each site the average response time and the expected number of spills, by land and by water. This was done for configurations 1, 3,4, and 4a, as shown in Tables 8-14, 8-15, 8-16, 8-17. The effect of the different configurations on the four major US Coastal areas plus Hawaii and Puerto Rico areas will be examined.

East Coast

There are two different site arrangements for the East Coast, represented in Table 8-14 (Configuration 1) and 8-15 (Configuration 3). In the first configuration, New England is covered by land and water sites at Portland ME and Providence RI. It is seen that the land capability at Portland ME responds to an average of .09 spills per year, and the water capability at Providence to an average of .13 spills per year. These are very low utilization rates for the equipment. One possible remedy is to eliminate the land capability at Portland and the water capability at Providence. Another is to combine both sites into one at Boston. The latter approach is taken in Configuration 3, Table 8-15. The new site at Boston has an average land response time of 4.0 hours, longer than either of the original two. In addition, the average land response time at New York goes up from 3.3 hours to 4.8 hours because it now covers some of the locations on the Connecticut coast formerly served by Providence. Philadelphia and Portsmouth VA are relatively unaffected. The net response time for an expected 9.88 spills per year on the East Coast is increased from 1.9 hours in Configuration 1 to 2.2 hours in Configuration 3. Thus the consolidation of the two New England sites into one has relatively little effect on the average East Coast response time.

One further improvement is seen to be possible from Table 8-15. The water capability at Boston has relatively low utilization, 0.30 spills per year on the average (one spill every 3 years). This water capability may be eliminated without seriously affecting response times, and with no increase in the percent of responses greater than six hours, because of the land site at Boston.

The large land response time for Portsmouth/Norfolk in Configuration 3 is due to coverage of Charleston SC (10.8 hours from Portsmouth) and the lower Potomac (4.9 hours from Portsmouth) as well as smaller ports in between. A remedy for this will be discussed later.

Gulf Coast

Three separate arrangements for the Gulf Coast are shown: Configurations 1,3 and 4. Attention will be directed first to the Louisiana-Texas Coast. Configuration 1 has greater coverage than the other two, comprising:

Pascagoula, MS
New Orleans, LA
Sabine TX (Port Arthur, Orange, Beaumont)
Galveston TX (Houston, Texas City, Freeport)
Port Aransas TX (Corpus Christi, Brownsville)

In Configuration 3 the Pascagoula water capability has been eliminated and its 1.15 spill rate is shifted to New Orleans land. New Orleans water continues to serve 2.70 spills/year, but the land response at New Orleans increases from 3.6 to 4.1 hours. The net effect is an increase from 2.7 hours for Pascagoula water plus New Orleans land, in Configuration 1, to 4.1 hours for New Orleans land alone in Configuration 3. This is a substantial shift for the 2.23 spills/year involved. Hence Pascagoula should be retained as a site.

A similar conclusion is reached when Sabine TX and Galveston TX (Configuration 3) are combined into Galveston TX alone (Configuration 4). The average response time increases from 2.3 hours to 3.2 hours, for the 2.32 spills/year involved.

TABLE 8-14 CONFIGURATION 1 ANALYSIS

	LAND		WATER	
EAST COAST	Response Time	Spills	Response Time	Spills
Portland, ME	3.5 Hrs	0.09	1.3 Hrs	0.66
Providence, RI	3.6	0.81	1.7	0.13
New York, NY	3.3	0.12	1.3	1.79
Philadelphia, PA	4.2	0.28	1.3	5.07
Portsmouth/Norfolk, VA	7.1	0.43	1.9	0.41
GULF COAST				
Clearwater, FL	6.9	0.73	1.8	0.09
Pascagoula, MS	---	----	1.8	1.15
New Orleans, LA	3.6	1.08	1.3	2.70
Sabine, TX	3.1	0.42	1.7	0.88
Galveston, TX	---	----	2.6	1.02
Port Aransas, TX	---	----	2.2	0.76

TABLE 8-14 (CONT.)

WEST COAST	Response Time	Spills	Response Time	Spills
San Pedro, Long Beach CA	4.0	0.42*	1.4	1.19*
San Francisco, CA			2.0	1.23*
Seattle, WA	5.3	.08*	1.8	.28*
Bellingham, WA			1.9	0.16*
GREAT LAKES				
Chicago, IL	2.6	0.16		
Buffalo, NY	5.2	.06		
HAWAII, HI				
Honolulu, HI			1.8	.18
PUERTO RICO				
San Juan, PR			2.0	.09

*Not adjusted for 1985 oil flows

TABLE 8-15 CONFIGURATION 3 ANALYSIS

	LAND		WATER	
NORTHEAST	Response Time	Spills	Response Time	Spills
Boston, MA	4.0 Hrs	1.13	1.4 Hrs	0.30
New York, NY	4.8	0.39	1.3	1.79
Philadelphia, PA	4.4	0.29	1.3	5.08
Portsmouth, VA	7.1	0.43	1.9	0.41
GULF COAST				
Clearwater, FL	6.9	0.73	1.8	0.09
New Orleans, LA	4.1	2.23	1.3	2.70
Sabine, TX	3.1	0.42	1.7	0.88
Galveston, TX			2.6	1.02
Port Aransas, TX			2.2	0.76
WEST COAST				
San Pedro/Long Beach, CA	4.0	0.42*	1.4	1.19*
San Francisco, CA			2.0	1.23*
Seattle, WA	4.1	0.24*	1.8	0.28*
GREAT LAKES				
Chicago, IL	3.2	0.18		

*Not adjusted for 1985 oil flows

TABLE 8-16 CONFIGURATION 4 ANALYSIS

	LAND		WATER	
EAST COAST	Response Time	Spills	Response Time	Spill
Boston, MA	4.0 Hrs	1.13	1.4	0.30
New York, NY	4.8	0.39	1.3	1.78
Philadelphia, PA	9.4	0.47	1.3	5.06
Portsmouth/Norfolk, VA	7.1	0.43	1.9	0.40
GULF COAST				
Clearwater, FL	6.9	0.73	1.8	0.08
New Orleans, LA	4.1	2.33	1.3	2.70
Galveston, TX	3.4	2.04	1.7	0.27
Port Aransas, TX			2.2	0.75
WEST COAST				
Los Angeles, CA	4.0	0.42*	1.4	1.18*
San Francisco, CA			2.0	1.23*
Seattle, WA	4.1	0.24*	1.8	0.28*

*Not adjusted for 1985 oil flows

TABLE 8-17 CONFIGURATION 4a ANALYSIS

	LAND		WATER	
	Response Time	Spills	Response Time	Spills
EAST COAST				
Boston, MA	4.0 Hrs	1.13	1.4 Hrs	0.30
New York, NY	4.6	0.37	1.3	1.78
Philadelphia, PA	4.2	0.28	1.3	5.06
Portsmouth/Norfolk, VA	4.6	0.20	1.9	0.40
GULF COAST				
Clearwater, FL	4.1	0.03	1.8	0.08
New Orleans, LA	4.0	2.19	1.3	2.70
Galveston, TX	3.4	2.04	1.7	0.27
Port Aransas, TX			2.1	0.74
Clearwater (Air)FL				
WEST COAST				
Los Angeles, CA	4.0	0.41	1.4	1.18*
San Francisco, CA			2.0	1.23*
Seattle, WA	3.9	0.24	1.8	0.28*

*Not adjusted for 1985 oil flows

A more profitable adjustment is to remove the water capability from Clearwater FL, where its utilization is low, and where a land capability already exists in all four configurations.

West Coast

It can be seen in Configuration 1, Table 8-14, that the water based capabilities at Seattle and Bellingham serve only .28 and .16 spills per year, before adjustment for 1985 oil flows. At the indicated levels the two water capabilities may be eliminated. Eliminating Bellingham actually decreases the average truck response time at Seattle, because Bellingham is, on the average, closer to Seattle than most of the sites Seattle serves by land.

As traffic increases on the West Coast in the 1980-85 period the water capability at Seattle, and possibly that at Bellingham, will become justified. If 80% of the Alaskan crude flow from the Trans Alaska Pipeline reaches the West Coast, then the expected spill rates shown would double.

Great Lakes

The removal of Buffalo from Configuration 1 places the entire burden of Great Lakes response on Chicago, as seen in Configuration 3. The average response time goes from 3.3 hours for 0.22 spills to 3.2 hours for .18 spills. The small reduction occurs because when Buffalo is removed Oswego Harbor is serviced by New York rather than Chicago, and Buffalo itself is serviced by Philadelphia, rather than Chicago. These shifts contribute slightly to the increase in response times of New York and Philadelphia discussed above. Therefore, the net effect on response times of the removal of Buffalo is not great, and the rearrangement appears to be desirable.

Hawaii and Puerto Rico

The major oil movement in 1976 in Hawaii was 166,000 tons at Barbers Point, about 8 n.miles west of Honolulu Harbor, which itself handles only about 7% of that amount. Hilo and Kahului which are more remote handle, together, less than 5% of the Barbers Point amount. The greatest spill threat, thus, is in the Barbers Point-Honolulu coastal area, and this can be reached effectively by the Direct Waterborne mode from either port. The Barbers Point

site not only has the greatest oil movement but also has the advantage of having three C130B's stationed there. This air mode may be adaptable to cover the islands to the north and south of Oahu.

Puerto Rico's main spill threat occurs at San Juan Harbor. Substantial traffic along the west and south coasts, however, presents an additional threat, as do the lightering operations off the Virgin Islands. These can be met only by water from San Juan, which is the station for the Buoy Tender Sagebrush and one or more WPB's. While the dimensions of Puerto Rico (about 30 n.miles by 90 n.miles) suggest land transport to the west and south coasts, this would be ineffective without vessel support, which is centered at San Juan.

Combined Configuration

The results of the above analysis are combined in Configuration 5, shown in Table 8-18. This Configuration has 14 sites, plus Hawaii and Puerto Rico. There are 10 land mode sites and 12 direct waterborne sites, with an overlap of 6. It can be seen from the bottom line that about 73% of the potential spills are handled by direct waterborne at an average response time of 1.6 hours, while the remaining 27% are handled by land at an average response time of 4.3 hours.

The West Coast sites show oil spill potential before adjustment for Alaskan crude movements in 1985. With the assumptions given in Appendix J for the disposition of Alaskan crude, the spill expectation for Seattle would be approximately twice the 0.52 spills/year shown. If this increased spill potential is realized in 1985 then the addition of direct waterborne sites in the Seattle and Bellingham/Anacortes areas would become advantageous as discussed previously.

The configuration presented has duplicate water and land capability at six sites: Philadelphia, New York, Los Angeles, New Orleans, Sabine TX, Portsmouth/Norfolk VA, which have substantial potential spills to be serviced by both modes. This substantially increases the amount of equipment required. There are at least two approaches to reducing the cost of such duplication:

TABLE 8-18 CONFIGURATION 5 ANALYSIS

	LAND		WATER		TOTAL	
EAST COAST	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Boston, MA	3.6 Hrs	1.43	--- Hrs	----	3.6 Hrs	1.43
New York, NY	4.8	0.40	1.3	1.79	2.0	2.19
Philadelphia, PA	4.4	0.30	1.4	5.07	1.5	5.37
Portsmouth/Norfolk, VA	7.1	0.43	1.9	0.41	4.6	0.84
GULF COAST						
Clearwater, FL	6.4	0.82	---	----	6.4	0.82
Pascagoula, MS	---	----	1.8	1.15	1.8	1.15
New Orleans, LA	3.6	1.08	1.3	2.71	2.0	3.78
Sabine, TX	3.1	0.42	1.7	0.88	2.2	1.30
Galveston, TX	---	----	2.6	1.03	2.6	1.03
Port Aransas, TX	---	----	2.2	0.76	2.2	0.76
WEST COAST						
Los Angeles, CA	4.0	0.42*	1.4	1.19*	2.1	1.61*
San Francisco, CA	---	----	2.0	1.23*	2.0	1.23*
Seattle, WA	3.0	0.52*	---	----	3.0	0.52*
GREAT LAKES						
Chicago, IL	3.2	0.18	---	----	3.2	0.18

TABLE 8-18 (CONT.)

	LAND		WATER		TOTAL	
HAWAII	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Barbers Point, HI	---	----	1.8	0.19	1.8	0.19
PUERTO RICO/VI						
San Juan, PR			2.0	0.09	2.0	0.09
	4.3	6.00	1.6	16.50	2.3	22.50

*Not adjusted for 1985 Alaskan Crude oil flows

Net Response Time, All Modes . . . . . 2.3 Hours

Percent Responses over 6 hours 4.4

(1) Eliminate the Direct Waterborne capability at some or all of those sites. The direct water ports of the six sites provide response to a total of 12.05 spills/year, at an average response time of 1.4 hours. Transfering these expected spills to land mode would increase the average response time for those spills by about 0.4 hours.* making it 1.8 hours. This would bring the system-wide average response time from 2.3 hours to 2.5 hours (about 15 minutes increase). No increase would occur in the percent of responses above 6 hours.

(2) Employ Transfer Waterborne in place of Direct Waterborne. This would cut in half the cost of the equipment itself, but add the cost of the trailer-launchers. Also, it would eliminate the back-up capability each mode provides the other.

The relative advantages and disadvantages of the three possibilities (duplicate land and direct waterborne, all land, transfer waterborne) depends strongly on the specific site, through such factors as (a) the availability of land storage space (b) the availability of protected mooring space, (c) the availability of launch ramps, (d) the availability of cranes or lifts to transfer truck-based equipment to a waiting sled or other towable vessel, or (e) the availability of buoy tenders to offload the truck for transport to the spill.

The Direct Waterborne and Land capabilities at the six duplicate sites will be treated as separate capabilities in the derivation of relative and absolute equipment levels. This will not preclude the possibility of eliminating Direct Waterborne, combining them into Transfer Waterborne, or leaving them distinct, on a site-by-site basis.

*The difference between the fixed response time for land, 1.75 hours, and the fixed response time for direct waterborne, 1.33 hours.

Air Response

The requirement that the six-hour response be achieved without dependence on air transport is met by the combined configuration (5) just described, in the same sense as it is met by the other configurations, i.e., 95% or more of the spills are responded to in less than six hours. For Configuration 5 about 4.5% of the spill responses exceed six hours. This number is due to the gaps in coverage along the Great Lakes and Southeast coast. It can be seen from Table 8-18 that Portsmouth/Norfolk VA and Clearwater FL have land response times that reflect their coverage of the Southeastern coast, while Philadelphia and New York have response times that include coverage of Oswego, Buffalo and parts of Lake Erie.

The response times over six hours just described can be substantially eliminated by the addition of an air site in the eastern United States. Table 8-19 shows the effect of a single air site (Clearwater FL) on the response times. The major land mode time reductions are as follows:

	(Configuration 5) No Air Site	(Configuration 5a) Air Site at Clearwater FL
Portsmouth/ Norfolk VA	7.1 hrs	4.6 hrs
Clearwater FL	6.4	2.7
Philadelphia PA	4.4	4.2
New York NY	4.8	4.6
Chicago IL	3.2	2.1

The same sharp reductions are achieved if the air site is placed at Elizabeth City NC yielding Configuration 5b, Table 8-20.

TABLE 8-19 CONFIGURATION 5a ANALYSIS

	LAND		WATER		AIR/LAND	
EAST COAST	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Boston, MA	3.6 Hrs	1.43	---	----	---	----
New York, NY	4.6	0.37	1.3	1.79	---	----
Philadelphia, PA	4.2	0.29	1.4	5.07	---	----
Portsmouth/Norfolk, VA	4.6	0.21	1.9	0.41	---	----
GULF COAST						
Clearwater, FL	2.7	0.13	---	----	5.3	1.05
Pascagoula, MS	---	----	1.8	1.15	---	----
New Orleans, LA	3.6	1.08	1.3	2.71	---	----
Sabine, TX	3.1	0.42	1.7	0.88	---	----
Galveston, TX			2.6	1.03	---	----
Port Aransas, TX			2.1	0.74	---	----
WEST COAST						
Los Angeles, CA	4.0	0.42	1.4	1.19	---	----
San Francisco, CA	---	----	2.0	1.23	---	----
Seattle, WA	2.9	0.52	---	----	---	----

TABLE 8-19 (CONT.)

GREAT LAKES	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Chicago, IL	2.1	0.14	---	----	---	----
HAWAII						
Barbers Point, HI	---	----	1.8	0.19	---	----
PUERTO RICO/VI						
San Juan, PR	---	----	2.0	0.09	---	----
	3.6	5.01	1.6	16.48	5.3	1.05

Net Response Time, All Modes . . . 2.2 Hours

Percent Responses over 6 Hours . . 0.67

	(Configuration 5) No Air Site	(Configuration 5b) Air Site at Elizabeth City, NC
Portsmouth/ Norfolk VA	7.1 hrs	3.82 hrs.
Clearwater FL	6.4	3.8
Philadelphia PA	4.4	4.1
New York NY	4.8	4.6
Chicago IL	3.2	2.0
Boston MA	3.6	3.5

In both cases the percent of spill responses greater than six hours drops sharply from the reference Configuration 5, but the average response time is roughly unchanged:

	Percent Responses >6 hours	Average Response Time, Hrs.
Configuration 5	4.55%	2.31
Configuration 5a	0.67	2.33
Configuration 5b	1.30	2.35

It will be noted that in Tables 8-19 and 8-20 that the land site associated with the air/land capability (i.e., Clearwater or Portsmouth) serves few spills/year on the average and should be considered for elimination. The same may be said for Chicago, which sees little use in the presence of an air/land capability in the East. Elimination of the land site at Clearwater, Portsmouth, or Chicago, however, would make the response times exceed six hours more than 5% of the time without the air capability, contrary to the site selection ground rule.

TABLE 8-20 CONFIGURATION 5b ANALYSIS

	LAND		WATER		AIR/LAND	
EAST COAST	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Boston, MA	3.5 Hrs	1.39	---	----	---	----
New York, NY	4.6	0.37	1.3	1.79	---	----
Philadelphia, PA	4.0	0.25	1.4	5.07	---	----
Portsmouth/Norfolk, VA	3.8	0.05	1.9	0.41	---	----
Elizabeth City, NC	---	----	---	----	5.7	1.16
GULF COAST						
Clearwater, FL	3.8	0.21	---	----	---	----
Pascagoula, MS	---	---	1.8	1.15	---	----
New Orleans, LA	3.6	1.08	1.3	2.71	---	----
Sabine, TX	3.1	0.42	1.7	0.88	---	----
Galveston, TX	---	---	2.6	1.03	---	----
Port Aransas, TX	---	---	2.1	0.74	---	----
WEST COAST						
Los Angeles, CA	4.0	0.42	1.4	1.19	---	----
San Francisco, CA			2.0	1.23	---	----
Seattle, WA	2.9	0.52	---	---	---	----

TABLE 8-20 (Cont'd.)

GREAT LAKES	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Chicago, IL	2.0	0.14	---	----	---	----
HAWAII						
Barbers Point, HI	---	----	1.8	0.19	---	----
PUERTO/VI						
San Juan, PR	---	----	2.0	0.09	---	----
	3.5	4.85	1.6	16.48	5.7	1.16

Net Response Time, All Modes. . . 2.2 Hours

Percent over 6 Hours. 1.30

9. EQUIPMENT LEVELS

The site selection procedure in the preceding section gives only the locations of the sites, but does not indicate how much equipment is to be stored at each site. In this section the distribution of recovery capability among the sites of a given configuration will be explored. A method will be applied to yield capability levels at the sites based on the expected number and volume distribution of spills within the area covered by each site. Attention will be restricted to capability levels for non-massive spills. The site configurations 5, 5a and 5b derived in the preceding Section will be assumed. Requirements for open water recovery capability will be derived separately from those for harbors. The objective of this Section is to assign both relative and absolute levels of the two types of capability to each site in the selected configurations.

This analysis is followed in Section 10 by an examination of the effectiveness of the postulated deployment relative to each of the massive spill scenarios. Finally, in Section 11, the possibility of reducing the derived equipment levels is analysed on the basis of three additional assumptions:

1. The open water response equipment is available for both harbor and open water spills.
2. The same inventory of equipment can be used for either overland or waterborne responses.
3. Assistance is available from adjacent sites.

9.1 METHOD

The initial approach taken to the question of equipment levels was to attempt to assign to each site adequate equipment to handle the largest non-massive spill expected within its coverage area (region). This approach was found to be unsatisfactory. Historic spill data from 1974-77 (Section 3) are inadequate to yield volume distributions for separate ports or regions. Although the

"largest expected non-massive spill" may be defined from the national volume distribution of Figure 3-5 (say, the 95% spill level), its use for all regions and ports would give the same value for the largest expected spill in all regions (i.e., for all sites). This is considered unrealistic because it would require all sites to maintain the maximum capability regardless of the spill probability at the site.

Because of the difficulties encountered in siting equipment on the basis of the largest spill expected, an alternate approach was taken. It starts from the acceptance of a single spill volume distribution for all regions in a configuration. It assumes that the probability of simultaneous spills over 50,000 gallons is negligible (See Appendix L). It next assumes that the equipment level at the i^{th} site of the configuration corresponds to a response capability r_i which is the largest spill size with which that equipment can deal effectively. It also assumes that the regions do not overlap,* and that the total response capability of the N sites in the configuration, is limited. Finally, it is assumed that the amount of oil recovered in a spill is proportional to the amount spilled, up to the response capability of the site, and equal to the response capability when greater amounts are spilled, as shown in Figure 9-1.

With the above assumptions, it is possible to allot equipment among the sites of a given configuration so as to maximize the mean value of the total amount of oil salvaged. The algorithm is derived in Appendix K. To carry out the allotment it is necessary to know only the distribution of spill volume (Figure 3-5, Section 3) and the average number $\bar{n}_i$ of spills in the i^{th} region, for $i = 1,2,3,\ldots N$. The $\bar{n}_i$ were obtained from the spill potential data base described in Appendix J and used for response time calculations in Section 8.

*The regions of most configurations do overlap. To apply this model a spill debarkation point in an overlapping area is assigned to the nearer of the two sites.

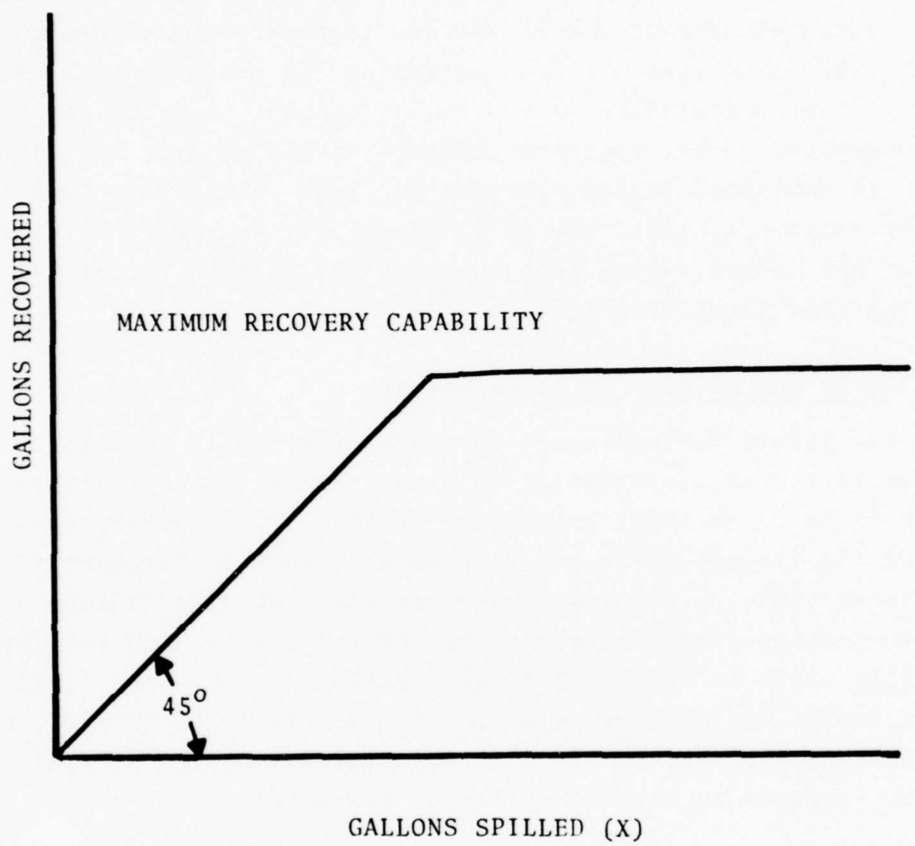


FIGURE 9-1. RECOVERY CAPABILITY MODEL

Open Water vs Harbor Capability

In order to estimate the levels required for open water recovery equipment as opposed to harbor recovery equipment the level assignments were made separately for open water spills and harbor spills. To estimate the open water spill potential the spill rates of Section 3 were applied to the coastal, foreign and Great Lakes oil movements plus estimated OCS production in 1985 in the spill potential data base. The adjustments made to the data for deepwater ports, transient tankers, trade shifts, and lightering were explained in the previous section. Similarly, to estimate harbor spill potential, the total of all oil movements for the harbor were taken, which included coastal, foreign, Great Lakes, internal and local traffic.

Massive vs Non-Massive Spill Capability

The levels derived apply to non-massive spill capability only. The spill volume distribution that was used is that of Figure 3-5, which is based on spill experience in 1974-1977. During this period the largest spill experienced was the Argo Merchant (7.6 million gallons). The levels derived with the distribution of Figure 3-5 therefore represent the optimal levels when the largest possible spill is about 8.0 million gallons. Equipment level requirements for massive spills, i.e., spills up to 30 million gallons, will be derived in a later section when the over-all system response to massive spills is evaluated.

U.S. Coast Guard vs. Non-USCG Capability

The response capabilities to be derived in this section represent total U.S. Coast Guard plus non-USCG capability at each site. In order to determine the Coast Guard requirement it is necessary to subtract from the totals the non-USCG response capability within the region. This will be done on the basis of available information about non-CG equipment inventories.

9.2 RELATIVE CAPABILITY LEVELS

The distribution of capability among the sites of a configuration depends on the total response capability of the configuration. Since the total response capability will be discussed in the following subsections, the relative distributions will be given here for several nominal total capability levels. They are shown for Configurations 5, 5a, and 5b in Table 9-1 through 9-6. The data in these tables were obtained from the allocation model described.

Some of the salient features on Tables 9-1 - 9-6 should be noted. First, it is seen that Philadelphia is assigned the greatest share of resources, as expected, in all cases. This share is greatest for low capability levels, dropping off as the national capability increases to 60 million gallons. The reason for this is that at low levels of total capability, resources are inadequate to cover the average spill volume. In the event of a spill in any region, the equipment at the site would be fully utilized. Therefore the resources are concentrated at those sites that expect the greatest number of spills, i.e., Philadelphia. As total resources increase, the Philadelphia capability begins to reach, and then exceed, the average spill size. As that occurs it becomes more profitable to invest capability in sites that are still unable to meet the average spill size and are more likely than Philadelphia to utilize all their resources in the event of a spill. These imbalances are adjusted for by the allotment algorithm as the total capability increases from 10 to 60 million gallons, as can be seen by the continuous decline in the relative capability assigned to Philadelphia.

Next it is seen by comparing Tables 9-2 and 9-1 that the open-water recovery capabilities are distributed similarly to the harbor capabilities. It should be realized, however, that the open-water recovery capability shown merely reflects the open-water traffic that originates or terminates in the associated port. The actual spill threat will be spread throughout the approaches to the port and along the adjacent coast. This should be taken account of in the final location of the equipment storage sites.

TABLE 9-1. RELATIVE EQUIPMENT LEVELS, PERCENT - HARBOR CAPABILITY, CONFIGURATION - 5

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	1.2	1.4	1.2	1.0	0.8
Philadelphia PA	W	30.8	27.0	20.3	16.9	12.2
New Orleans LA	L	3.9	3.7	5.2	5.8	6.4
New Orleans LA	W	13.3	15.7	15.1	13.7	10.8
New York NY	L	1.7	1.7	1.3	1.1	1.4
New York NY	W	6.0	10.0	9.4	10.2	9.3
San Francisco CA	W	4.1	4.3	6.5	6.5	7.3
Galveston TX	W	3.8	3.5	4.7	5.4	6.0
Los Angeles CA	L	1.8	1.7	1.3	1.1	1.4
Los Angeles CA	W	4.0	4.2	6.1	6.2	7.1
Pascagoula MS	W	4.0	4.0	5.9	6.1	6.9
Sabine TX	L	1.8	1.8	1.3	1.2	1.4
Sabine TX	W	3.7	2.6	2.9	4.4	4.8
Port Aransas TX	W	3.4	2.2	2.5	3.1	4.2
Boston MA	L	4.4	6.8	7.7	7.6	8.2
Portsmouth VA	L	1.9	1.8	1.3	1.2	1.5
Portsmouth VA	W	1.7	1.7	1.3	1.2	1.4
Seattle WA	L	2.5	1.9	1.4	1.6	2.6
Clearwater FL	L	3.6	2.3	2.7	3.8	4.5
Chicago IL	L	0.9	0.7	0.7	0.8	0.6
Barbers Pt. HI	W	0.9	0.7	0.8	0.8	0.7
San Juan PR	W	0.5	0.4	0.4	0.3	0.4
Totals	100%					

TABLE 9-2. RELATIVE EQUIPMENT LEVELS, PERCENT

- OPEN WATER CAPABILITY, CONFIGURATION - 5

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.7	0.7	0.7	0.6
Philadelphia PA	W	36.7	27.9	21.6	16.7	11.8
New Orleans LA	L	3.7	2.6	2.9	4.4	5.2
New Orleans LA	W	4.7	7.8	8.4	8.5	8.5
New York NY	L	1.6	1.6	1.3	1.0	1.3
New York NY	W	6.9	10.6	10.3	10.6	9.4
San Francisco CA	W	4.4	5.4	7.2	6.8	7.8
Galveston TX	W	4.0	3.7	5.3	5.8	6.7
Los Angeles CA	L	2.0	1.8	1.4	1.1	1.9
Los Angeles CA	W	4.7	7.9	8.4	8.6	8.6
Pascagoula MS	W	3.9	3.5	4.7	5.5	6.4
Sabine TX	L	0.5	0.3	0.3	0.2	0.3
Sabine TX	W	3.9	3.4	4.6	5.4	6.3
Port Aransas TX	W	3.8	2.9	3.5	4.8	5.6
Boston MA	L	7.1	10.8	10.7	10.8	9.4
Portsmouth VA	L	1.6	1.6	1.3	1.0	1.3
Portsmouth VA	W	1.5	1.5	1.3	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.1	1.3
Clearwater FL	L	3.7	2.3	2.8	3.9	4.7
Chicago IL	L	0.8	0.5	0.5	0.5	0.6
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6

Totals 100%

TABLE 9-3. RELATIVE EQUIPMENT LEVELS, PERCENT

- HARBOR CAPABILITY, CONFIGURATION 5a -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	1.2	1.3	1.1	1.0	0.8
Philadelphia PA	W	30.9	26.9	20.0	16.7	12.1
New Orleans LA	L	3.9	3.7	5.1	5.7	6.4
New Orleans LA	W	13.4	15.6	14.9	13.5	10.7
New York NY	L	1.6	1.6	1.2	1.1	1.2
New York NY	W	6.0	9.9	9.2	10.0	9.2
San Francisco CA	W	4.1	4.3	6.4	6.4	7.3
Galveston TX	W	3.9	3.4	4.6	5.4	6.0
Los Angeles CA	L	1.8	1.7	1.3	1.1	1.4
Los Angeles CA	W	4.0	4.1	6.0	6.2	7.0
Pascagoula MS	W	4.0	3.9	5.5	5.9	6.6
Sabine TX	L	1.8	1.7	1.3	1.1	1.4
Sabine TX	W	3.7	2.6	2.9	4.3	4.7
Port Aransas TX	W	3.4	2.2	2.3	2.9	4.1
Boston MA	L	4.4	6.7	7.6	7.5	8.2
Portsmouth VA	L	0.9	0.8	0.9	0.8	0.7
Portsmouth VA	W	1.8	1.7	1.3	1.1	1.4
Seattle WA	L	2.5	1.9	1.4	1.5	2.5
Clearwater FL	L	0.7	0.5	0.5	0.5	0.5
Clearwater FL	A	3.9	3.5	4.8	5.5	6.1
Chicago IL	L	0.8	0.6	0.5	0.6	0.6
Barbers Pt. HI	W	0.9	0.7	0.8	0.8	0.6
San Juan PR	W	0.5	0.4	0.4	0.3	0.4

Totals 100%

TABLE 9-4. RELATIVE EQUIPMENT LEVELS, PERCENT

- OPEN WATER CAPABILITY, CONFIGURATION 5a -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.6	0.7	0.7	0.6
Philadelphia PA	W	37.0	27.8	21.2	16.6	11.6
New Orleans LA	L	3.8	2.6	2.9	4.3	5.1
New Orleans LA	W	4.7	7.7	8.2	8.4	8.4
New York NY	L	1.4	1.5	1.2	1.0	1.1
New York NY	W	1.0	10.5	10.2	10.5	9.2
San Francisco CA	W	4.4	5.4	7.1	6.7	7.7
Galveston TX	W	4.0	3.7	5.2	5.7	6.6
Los Angeles CA	L	2.0	1.8	1.3	1.1	1.9
Los Angeles CA	W	4.7	7.9	8.3	8.5	8.5
Pascagoula MS	W	4.0	3.4	4.5	5.3	6.2
Sabine TX	L	0.5	0.3	0.3	0.2	0.2
Sabine TX	W	4.0	3.4	4.5	5.3	6.2
Port Aransas TX	W	3.8	2.8	3.2	4.6	5.4
Boston MA	L	7.2	10.8	10.5	10.7	9.3
Portsmouth VA	L	0.5	0.4	0.4	0.3	0.4
Portsmouth VA	W	1.5	1.5	1.2	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.0	1.3
Clearwater FL	L	0.5	0.4	0.4	0.3	0.4
Clearwater FL	A	4.1	3.8	5.5	5.9	6.8
Chicago IL	L	0.5	0.4	0.4	0.4	0.5
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6

Totals 100%

TABLE 9-5. RELATIVE EQUIPMENT LEVELS, PERCENT

- HARBOR CAPABILITY, CONFIGURATION 5b -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	1.1	1.1	1.0	0.9	0.7
Philadelphia PA	W	31.0	26.9	19.9	16.7	12.0
New Orleans LA	L	3.9	3.7	5.1	5.7	6.3
New Orleans LA	W	13.4	15.7	14.8	13.5	10.7
New York NY	L	1.6	1.6	1.2	1.1	1.2
New York NY	W	6.0	10.0	9.2	10.0	9.2
San Francisco CA	W	4.1	4.3	6.3	6.4	7.2
Galveston TX	W	3.9	3.5	4.6	5.3	6.0
Los Angeles CA	L	1.8	1.7	1.3	1.1	1.4
Los Angeles CA	W	4.0	4.1	6.0	6.2	7.0
Pascagoula MS	W	4.0	4.0	5.7	6.1	6.8
Sabine TX	L	1.8	1.7	1.3	1.1	1.4
Sabine TX	W	3.7	2.6	2.9	4.3	4.7
Port Aransas TX	W	3.4	2.2	2.3	2.9	4.1
Boston MA	L	4.4	6.3	7.3	7.1	8.0
Elizabeth City NC	A	4.0	4.0	5.8	6.1	6.8
Portsmouth VA	L	0.5	0.3	0.3	0.2	0.2
Portsmouth VA	W	1.8	1.7	1.3	1.1	1.4
Seattle WA	L	2.5	1.9	1.4	1.5	2.5
Clearwater FL	L	1.0	0.9	0.9	0.8	0.7
Chicago IL	L	0.8	0.6	0.5	0.6	0.6
Barbers Pt. HI	W	0.9	0.7	0.8	0.8	0.6
San Juan PR	W	0.5	0.4	0.4	0.3	0.4

Totals 100%

TABLE 9-6. RELATIVE EQUIPMENT LEVELS, PERCENT

- OPEN WATER CAPABILITY, CONFIGURATION 5b -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.6	0.7	0.7	0.6
Philadelphia PA	W	37.1	27.8	21.2	16.5	11.6
New Orleans LA	L	3.8	2.6	2.9	4.3	5.1
New Orleans LA	W	4.7	7.7	8.2	8.4	8.4
New York NY	L	1.4	1.5	1.2	1.0	1.1
New York NY	W	7.0	10.5	10.1	10.5	9.2
San Francisco CA	W	4.4	5.4	7.1	6.7	7.7
Galveston TX	W	4.0	3.7	5.2	5.7	6.6
Los Angeles CA	L	2.9	1.8	1.3	1.1	1.8
Los Angeles CA	W	4.8	7.9	8.3	8.5	8.5
Pascagoula MS	W	4.0	3.5	4.7	5.4	6.3
Sabine TX	L	0.5	0.3	0.3	0.2	0.2
Sabine TX	W	4.0	3.4	4.5	5.3	6.2
Port Aransas TX	W	3.8	2.8	3.2	4.6	5.4
Boston MA	L	6.9	10.4	10.0	10.4	9.2
Elizabeth City NC	A	4.2	4.1	6.1	6.2	7.2
Portsmouth VA	L	0.0	0.0	0.0	0.0	0.0
Portsmouth VA	W	1.5	1.5	1.2	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.0	1.3
Clearwater FL	L	0.8	0.6	0.6	0.6	0.6
Chicago IL	L	0.5	0.4	0.4	0.3	0.4
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6

Totals 100%

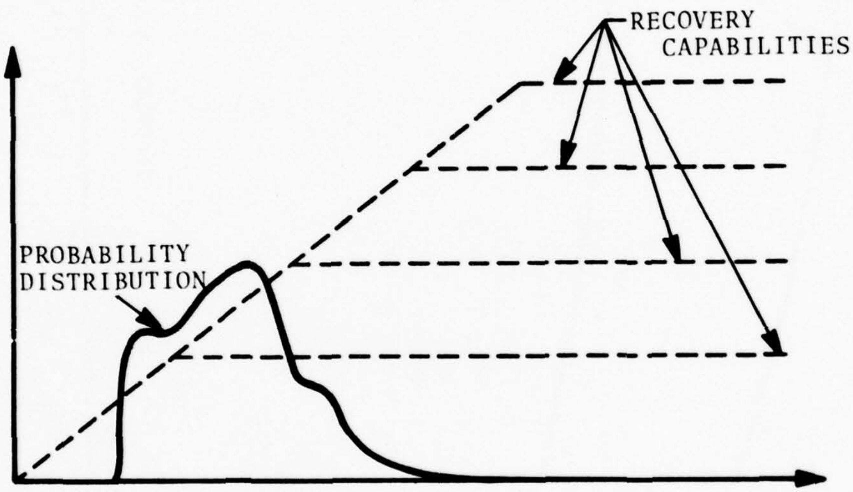
Finally, the effect on the relative capability levels of the air/land site is seen to be minimal. The air/land site at Clearwater FL receives 3.9% of the total capability, almost all of which comes from the Clearwater land site and the Portsmouth/Norfolk land site. This is seen by comparing Table 9-3 to 9-1. Similarly, when the air/land capability is placed at Elizabeth City NC, (Table 9-5) the result is a shift of the Clearwater and Portsmouth/Norfolk land capability to Elizabeth City.

9.3 ABSOLUTE CAPABILITY LEVELS

The total recovery capability may be set either by external conditions, such as budgetary considerations, or by internal efficiency criteria. The latter approach will be taken here, since any external conditions must be set outside the scope of the present study.

The amount of oil recovered in a spill, as given by the recovery model of Figure 9-1, depends on the amount x of oil spilled. The probability density distribution of x is similar to the solid line in Figure 9-2, obtained from the cumulative distribution of Figure 3-5. The dashed lines in Figure 9-2 represent the recovery capability for the site. As the break point in the dashed lines increases, more and more of the spill distribution lies within the recovery capability, i.e., to the left of the bend. Eventually further increases in recovery capability have little or no effect on the amount recovered. Therefore, as the total capability of the configuration increases, and is assigned by the algorithm to the individual sites, the total amount of oil actually recovered can be expected to reach some saturation level as the site recovery capabilities move to the right of their spill volume distributions.

The total amount of oil recovered per year on the average for Configuration 5 is plotted against total capability of the configuration in Figure 9-3. The upper curve in the Figure applies



GALLONS SPILLED (X)

FIGURE 9-2. SPILL PROBABILITY AND SPILL RECOVERY VS SPILL SIZE

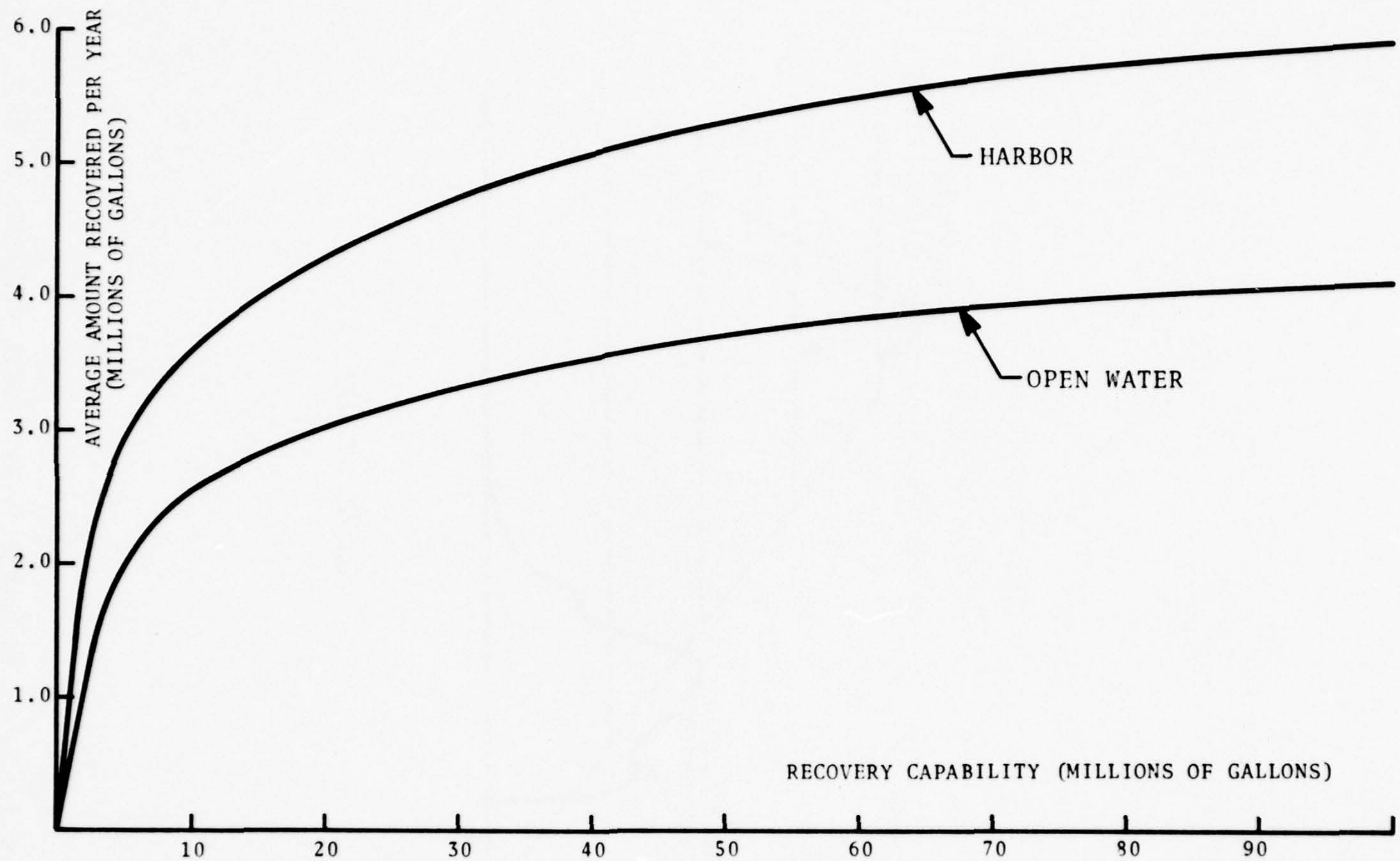


FIGURE 9-3. EXPECTED ANNUAL RECOVERY VS TOTAL CAPABILITY

to harbor capability and recovery; the lower curve applies to open water. It can be seen that the expected amount recovered rises rapidly at first and then more slowly as the total capability exceeds the 10 million gallon range. Harbor recovery appears to approach about 6.4 million gallons asymptotically, while open water recovery appears to approach about 4.2 million gallons. The curves for Configurations 5a and 5b are almost identical and are not shown for that reason.

An absolute level of capability may be selected from Figure 9-3 by setting a lowest acceptable limit to the ratio of incremental total recovery to incremental total capability. A lowest value of 0.1 was tried first, that is, the total capability K was set at a value such that the slope of the curve is 0.1 (1/10 gallon recovered per gallon increase in capability,

$$\Delta\overline{R}/\Delta K = 0.1).$$

For the harbor recovery capability this criterion gives $K = 10$ million gallons and $\overline{R} = 3.6$ million gallons/year; for open water recovery the criterion gives $K = 8$ million gallons, and $\overline{R} = 2.3$ million gallons/year. In both cases the resulting annual recovery $\overline{R}$ is about 55% of its asymptotic value.

An alternate approach to selecting a total capability K is to select a recovery goal as a percentage of maximum possible recovery. Such a goal might place $\overline{R}$ at, say, 80% of its asymptotic value, and yield $K = 42$ million gallons of harbor capability, and $K = 30$ millions of open water capability. Some possible recovery goals, and corresponding total capabilities are listed:

Recovery Goal	Harbor Capability	Open Water Capability
95%	>100 million gals	80 million gals
90%	66	56
80%	42	30
65%	18	14
50%	6.5	5.5

The incremental recovery/capability ratios for these goals are well below 1/10, bringing out the fact that high recovery percentages can be achieved only by low incremental efficiencies. The over-all efficiencies, however, are not nearly as low, as seen in the following:

Recovery Goal: Percent of Maximum Possible Recovery	Overall Efficiency: (Expected Amount Recovered per Year) / (Total Recovery Capability) — Harbor	Open Water
95%	6%	5%
90%	8.3	6.7
80%	12.4	11.0
65%	23.3	19.6
50%	49.0	38.0

It is highly desirable that recovery goals be set well above 50%, if possible, so that the system may be considered successful more often than not. It is possible to do so with overall efficiencies of about 10%. Accordingly a goal of 80% is assumed for the operating point for the overall recovery goal, with corresponding total capabilities of 40 million gallons for harbor and 30 million gallons for open water.

9.4 EQUIPMENT LEVELS

The above requirements are stated in terms of gallons of oil recovered, not equipment. Moreover, they apply to the total of US Coast Guard plus non-US/Coast Guard equipment. To derive specific US Coast Guard equipment requirements, the non-US Coast Guard equipment available in each site's region must be converted to gallons of recovery capability and subtracted from the total requirement given above for that site. The difference indicates the net US Coast Guard capability to be provided at the site.

Non-US Coast Guard equipment availability was estimated from the USCG spill cleanup inventory compiled in FY 78. Because the data base was still in process of compilation and debugging at the time this report was prepared it provided only a crude estimate

of the recovery equipment available outside of the US Coast Guard. The details of the data extracted from the inventory are given in Appendix M, as are the assumptions employed to convert the numbers of pumps, barriers, skimmers, barges, etc., to gallons of recovery capability.

The results of comparing the external capability for each region to the capability requirements previously derived are shown in Table 9-7 for harbors and in Tables 9-8 for open water. From these tables several results emerge:

(1) Non-USCG pumping capability is, in general far greater than the required total capability at almost every site. Since these pumps are often employed for offloading and transferral in the normal course of business at major ports, and a large supply exists.

(2) The non-USCG storage capability shown is highly variable from site to site. This is due to gaps in the data. In particular, the barge availability in Texas is probably greater than shown. Also, for many ports, the number of units was reported, but not the total capacity.

(3) Harbor skimmers from non-USCG sources generally have less capability than called for at the sites. According to the data, the external open-water capability is greater than the harbor capability. However, the classification of a skimmer as "harbor" or "open water" in the inventory seems rather arbitrary, and many of those listed under "open water" may in fact be unable to operate effectively in more than 3 ft. waves. A better approximation to non-USCG capability may be to assign all skimming capability to harbors.

TABLE 9-7 NON-USCG HARBOR CAPABILITY

(THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY	NON-USCG CAPABILITY (1)			
		PUMPS	STORAGE	SKIMMING	CONTNMNT
Philadelphia PA	7,160	67,300	27,300	40	25,600
New Orleans LA	7,800	735,900	10	250	11,600
New York NY	4,520	38,700	100	40	12,800
San Francisco CA	2,600	104,000	400	1,200	53,500
Galveston TX	2,160	7,200	0	0	200
Los Angeles CA	2,920	13,500	1,400	300	7,700
Pascagoula MS	2,440	6,000	200	100	11,600
Sabine TX	2,200	79,900	20	200	11,200
Port Aransas TX	1,240	0	0	200	11,600
Boston MA	3,040	102,000	1,600	1,300	4,100
Portsmouth VA	920	16,000	600	1,300	11,600
Seattle WA	640	50,800	300	400	15,500
Clearwater FL	1,520	14,400	1,500	300	5,537
Chicago IL	320	350,500	6,200	0	6,500

(1) Adjusted. See Appendix M

TABLE 9-8 NON-USCG OPEN WATER CAPABILITY
(THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY	NON-USCG CAPABILITY[1]			
		PUMPS	STORAGE	SKIMMING	CONTNMNT
Philadelphia PA	6690	69,000	27,300	32	0
New Orleans LA	3390	754,700	10	190	0
New York NY	3480	39,600	100	32	0
San Francisco CA	2160	106,600	400	880	0
Galveston TX	1590	7,300	0	0	0
Los Angeles CA	2940	13,800	1,400	260	0
Pascagoula MS	1410	6,000	150	100	0
Sabine TX	1470	81,900	20	130	0
Port Aransas TX	1050	0	0	160	0
Boston MA	3210	104,700	1,600	960	32
Portsmouth VA	780	16,400	600	980	0
Seattle WA	390	52,100	300	320	0
Clearwater FL	840	14,800	1,500	230	0
Chicago IL	150	359,400	6,200	0	0

(1) Adjusted. See Appendix M

(4) Non-USCG harbor barrier capability exceeds the required total capability at most sites.

(5) The open water barrier is that classified in the inventory as operating in wave heights greater than five feet. The specific capabilities of the booms so listed should be examined for each site before net USCG requirements are determined.

When the available external capability is allowed for, the net required USCG capability is obtained. This is shown in Tables 9-9 for harbors and 9-10 for open water. Several assumptions were made in these tables. It was assumed that non-USCG pumps, skimmers and barriers would be available for harbor use only. Further, it was assumed that non-USCG barges would arrive on the spill location on the 18th hour for a harbor spill and on the 30th hour for an open water spill and that Coast Guard temporary storage containers would have to be employed until their arrival. It was assumed that USCG recovery operations would commence on the 8th hour for harbor spills and 10th hour for open water spills.

The requirements listed in Tables 9-9 and 9-10 do not show separate land- and water-based capabilities for those locations of Configuration 5 that have both types of sites (Philadelphia, New York, Sabine, Portsmouth/Norfolk, Los Angeles). The two types of capability were combined in order to subtract off non-USCG capability, which is not available in separate land- and water-based lists. In order to obtain estimates of the required USCG land- and water-based capabilities at each location, the requirements of Tables 9-9 and 9-10 were pro-rated to land and to water by means of the L and W percentages of Tables 9-1 and 9-2. The results are shown in Tables 9-11 and 9-12.

TABLE 9-9 REQUIRED USCG HARBOR CAPABILITY
(THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY (1)	REQUIRED USCG CAPABILITY			
		PUMPS (2)	STORAGE (3)	SKIMMING (4)	CONTNMNT
Philadelphia PA	7160	0	820/1800	7120	0
New Orleans LA	7800	0	900/1980	7350	0
New York NY	4520	0	520/1145	4480	0
San Francisco CA	2600	0	300/660	1400	0
Galveston TX	2160	0	250/550	2160	2000
Los Angeles CA	2920	0	330/740	2600	0
Pascagoula MS	2440	0	280/620	2340	0
Sabine TX	2240	0	250/560	2000	0
Port Aransas TX	1240	1240	140/314	1040	0
Boston MA	3040	0	350/770	2740	0
Portsmouth VA	960	0	100/230	0	0
Seattle WA	640	0	70/160	240	0
Clearwater FL	1520	0	170/390	1220	0
Chicago IL	320	0	40/80	320	0
	39560*	1240	4520/10000	35210	2000

(1) Total of land-based and water-based capability for configuration 5 (Table 9-1) for total U.S. capability of 40 million gallons.

(2) Based on immediate availability of non-USCG pumping capability

(3) Offloading/Skimming; temporary storage requirement based on 8 hr start time and 96 hours of operation with storage required up to 18th hour only.
Skimmer recovery efficiency 45%

(4) Based on non-USCG skimming capability shown in Table 9-7.

* 40 Million gallons, less Hawaiian and Puerto Rican capabilities.

TABLE 9-10 REQUIRED USCG OPEN WATER CAPABILITY
(THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY (1)	REQUIRED USCG CAPABILITY			
		PUMPS (2)	STORAGE (3)	SKIMMING (4)	CONTNMNT
Philadelphia PA	6690	6690	1100/2230	6690	6690
New Orleans LA	3390	3390	560/2410	3390	3390
New York NY	3480	3480	580/2470	3480	3480
San Francisco CA	2160	2160	360/1540	2160	2160
Galveston TX	1590	1590	270/1130	1590	1590
Los Angeles CA	2940	2940	490/2090	2940	2940
Pascagoula MS	1410	1410	230/1000	1410	1410
Sabine TX	1470	1470	240/1050	1470	1470
Port Aransas TX	1050	1050	170/750	1050	1050
Boston MA	3210	3210	530/2280	3210	3210
Portsmouth VA	780	780	130/550	780	780
Seattle WA	390	390	65/280	390	390
Clearwater FL	840	840	140/600	840	840
Chicago IL	150	150	25/110	150	150
	29550*	29550	4890/21000.	29550.	29550.

(1) Total of land-based and water-based capability for Configuration 5, (Table 9-2) at 30 million gallons total U.S. capability.

(2) Based on unavailability of non-USCG pumping capability

(3) Offloading/Skimming; temporary storage requirement based on 10 hr. start time, 72 hours of skimming, and 120 hours of pumping with storage required up to 30th hour only. Skimmer recovery efficiency 45%.

(4) Based on non-availability of non-USCG equipment for open-water use.

* 30 million gallons, less Hawaiian and Puerto Rican capabilities.

TABLE 9-11. REQUIRED USCG HARBOR CAPABILITY, LAND- AND WATER-BASED (THOUSANDS OF GALLONS)

SITE	TYPE	REQUIRED USCG CAPABILITY			
		PUMPS	STORAGE (1)	SKIMMING	CONTNMNT
Philadelphia PA	L	0	46/100	398.	0
Philadelphia PA	W	0	774/1700	6722.	0
New Orleans LA	L	0	267/589	2246.	0
New Orleans LA	W	0	632/1390	5304.	0
New York NY	L	0	51/111	436.	0
New York NY	W	0	469/1034	4044.	0
San Francisco CA	W	0	300/660	1400.	0
Galveston TX	W	0	250/550	2160.	2000.
Los Angeles CA	L	0	50/112	392.	0
Los Angeles CA	W	0	280/628	2208.	0
Pascagoula MS	W	0	280/620	2340.	0
Sabine TX	L	0	50/122	400.	0
Sabine TX	W	0	200/448	1600.	0
Port Aransas TX	W	1240	140/314	1040.	0
Boston MA	L	0	350/770	2740.	0
Portsmouth VA	L	0	50/120	0.	0
Portsmouth VA	W	0	50/120	0.	0
Seattle WA	L	0	70/160	240.	0
Clearwater FL	L	0	170/390	1220.	0
Chicago IL	L	0	40/80	320.	0
Barbers Pt*HI	W	320	320/320	320.	320.
San Juan* PR	W	120	120/120	120.	120.
		1680	4960/10440	35650.	2440.

(1) Offloading/Skimming

*Non-USCG capability not allowed for.

TABLE 9-12. REQUIRED USCG OPEN WATER CAPABILITY LAND- AND WATER-BASED (THOUSANDS OF GALLONS)

SITE	TYPE	PUMPS	STORAGE (1)	SKIMMING	CONTNMNT
		REQUIRED USCG CAPABILITY			
Philadelphia PA	L	210	35/149	210.	210.
Philadelphia PA	W	6480	1065/4601	6480.	6480.
New Orleans LA	L	870	144/618	870.	870.
New Orleans LA	W	2520	416/1790	2520.	2520.
New York NY	L	390	65/267	390.	390.
New York NY	W	3090	515/2193	3090.	3090.
San Francisco CA	W	2160	360/1540	2160.	2160.
Galveston TX	W	1590	270/1130	1590.	1590.
Los Angeles CA	L	420	70/300	420.	420.
Los Angeles CA	W	2520	420/1790	2520.	2520.
Pascagoula MS	W	1410	230/1000	1410.	1410.
Sabine TX	L	90	15/64	90.	90.
Sabine TX	W	1380	225/986	1380.	1380.
Port Aransas TX	W	1050	170/750	1050.	1050.
Boston MA	L	3210	530/2280	3210.	3210.
Portsmouth VA	L	390	65/275	390.	390.
Portsmouth VA	W	390	65/275	390.	390.
Seattle WA	L	390	65/280	390.	390.
Clearwater FL	L	840	140/600	840.	840.
Chicago IL	L	150	25/110	150.	150.
Barbers Pt* HI	W	330	330/330	330.	330.
San Juan* PR	W	150	150/150	150.	150.
		30030.	5370/21480	30030.	30030.

*Non-USCG capability not allowed for.

(1) Offloading/Skimming.

The final step is to convert the net required USCG capabilities into numbers of baseline equipment units. These units are summarized in Section 7.1, have capabilities as follows:

ADAPTS: Double stage pump with 300 ft. hose, prime mover, stripping pump, spare parts. 1000 gal/min nominal pumping rate.

OWORS/Barrier: Lockheed disk skimmer with USCG 612 ft. barrier (employs type F Dracone Barge, barrier towing vessels (2) work and support vessel). 300 gallons/minute recovery rate.

OWOCRS: USCG open water barrier with integral weir skimmers, pumps, hose, type F Dracone Barge, support vessel, two towing vessels. 300 gallons/minute recovery rate.

POHSSC: Type OW Dracone Barge for offloading, (250,000 gallon capacity) Type F for skimming (42,000 gallons capacity)

To estimate the net capability in gallons of the baseline equipment, the assumptions of Table 9-13 were made, with the results given in the same Table. It should be noted that the POHSSC's are assumed to be replaced by barges after 18 hours of operation in harbors, and 30 in open water. In practice, since the OWORS and OWOCRS must trail their containers after them, the assumption is that the POHSSC will be emptied into a hard hull and recycled starting at the 18th or 30th hour. If this is not feasible because of lack of pumping capability, the POHSSC requirement would be as shown in parentheses, which is substantially higher. Because of the assumptions on barge availability, an amount of USCG temporary storage in the form of POHSSC units is required independently of the need for USCG pumping capability. The method of determining equipment units from Tables 9-9 through 9-13 is as follows:

ADAPTS: The number of units required is equal to the REQUIRED USCG CAPABILITY shown under

TABLE 9-13 BASELINE PER UNIT CAPABILITY

	ADAPTS & POHSSC TYPE OW	OWORS & POHSSC TYPE F	OWOCRS & POHSSC TYPE F
HARBOR			
Nominal Recovery Rate (g/m)	1000	300(1)	300(2)
Start Time (hrs.)	8	8	8
Stop Time (hrs.)	96	96	96
Utilization (hr/day/unit)	22	12	12
Maneuvering Efficiency (%)(3)	90	50	50
Net Recovery (Gal/Unit/Spill)	$4,356 \times 10^3$	396×10^3	396×10^3
Number of POHSSC Req'd/Unit(4)	2.0	1.1(9.7)	2.2(19.4)
OPEN WATER			
Nominal Recovery Rate (g/m)	1,000	300(1)	300(2)
Start Time (Hrs.)	10	10	10
Stop Time	120	72	72
Utilization (Hr/Day/Unit)	20	10	10
Maneuvering Efficiency (%)(3)	90	50	50
Net Recovery (Gal/Unit/Spill)	$4,950 \times 10^3$	233×10^3	233×10^3
Number of POHSSC Req'd/Unit(5)	3.6	1.8(5.6)	3.6(11.2)

(1) Based on 100% recovery efficiency and 600 ft barrier at 1 knot

(2) Based on 50% recovery efficiency, 600 g/m pumping rate

(3) Percent of operating time that oil is actually being recovered

(4) Based on barge availability at 18th hour, 85% filling

(5) Based on barge availability at 30th hour, 85% filling

PUMPS in Tables 9-9, 9-10 or Tables 9-11, 9-12, divided by 4,356 x 10^3 for harbor-- and 4,950 x 10^3 for open water, rounded up to the next integer.

POHSSC, Type OW: this is the REQUIRED USCG CAPABILITY for STORAGE (number to left of slash) divided by 250,000, rounded to next largest integer.

OWORS-Barrier: The number of units required equals the REQUIRED USCG CAPABILITY for SKIMMING divided by 396,000 for harbor and 233,000 for open water, rounded to the next largest integer.

OWOCRS: The number of units required equals the REQUIRED USCG CAPABILITY for SKIMMING divided by 396,000 for harbor and 233,000 for open water, rounded to the next largest integer.

POHSSC, Type F: The harbor requirement is 1.1 times the number of OWORS-Barrier units or 2.2 times the number of OWOCRS units, rounded to the next largest integer. For open water, the requirement is 1.8 times the number of OWOCRS units, rounded to the next largest integer.

When the above procedure is applied to the total required USCG capabilities, shown at the bottom of Tables 9-11 and 9-12, the results are as shown in Table 9-14. Because of rounding the equipment requirements based on total U.S. capability is less than the sum of the units required for the separate sites. Moreover, assigning units to separate land- and water-based sites results in substantially more equipment than assigning them to combined sites, again because of rounding to whole units. The effect is most pronounced in the case of ADAPTS units, because of their high capacity relative to most site requirements, which results in upward rounding to a single unit at most sites.

The total unit requirements of Table 9-14 will serve as an approximate measure of equipment availability for response to massive spills, as determined by the three scenarios of section 4. The response afforded by Configuration 5 to the three hypothetical massive spills will be examined in the next section. Then, in section 11, a final system configuration will be arrived at, taking into account the massive spill response requirements, as well as other system-level considerations such as harbor/open water combination, land- and water-based capabilities, air-based response, and site-to-site assistance.

TABLE 9-14. EQUIPMENT UNITS CORRESPONDING TO TOTAL CAPABILITY, CONFIGURATION 5

	Harbor	Open Water
OFFLOADING		
ADAPTS 2-Stage	1	7
POHSSC Type OW	20	22
SKIMMING		
1. OWORS-Barrier	90	129
POHSSC Type F	99	232
2. OWOCRS	90	129
POHSSC Type F	198	464

REFERENCE FOR SECTION 9

9-1 Beyer, A.H. and L.J. Painter, "Estimating the Potential for Future Oil Spills from Tankers, Offshore Development, and Onshore Pipelines," in Proceedings of the 1977 Oil Spill Conference, March 8-10, 1977, New Orleans LA, American Petroleum Institute Publication No. 4284.

10. MASSIVE SPILL RESPONSE

In this section of the report the ability of the selected site configuration to respond to the massive spills described in Section 4 will be examined. The analysis will be based on the recovery requirements to be derived for each spill scenario in terms of offloading (Section 10.1.1) and skimming (Section 10.1.2). After these requirements have been established, three possible logistic strategies will be defined, and the response capability of each strategy will be determined for the selected configuration.

10.1 OIL RECOVERY REQUIREMENTS

The spill scenario events of Section 4 were constructed as if no recovery operations were in progress. The offloading requirements are based on assumptions regarding the amounts of oil that have been or may be spilled. The upper limit on the skimming requirement is established by the assumption that circumstances prevent offloading so that all of the discharged oil is available for skimming from the ocean's surface.

10.1.1 Offloading Requirements

Offloading requirements will be derived for Scenarios A and B by ascertaining the net amount in the vessels that could be offloaded at any time. Offloading does not apply to the oil well release of Scenario C.

Scenario A

PACIFIC PIGEON grounded at 0210 on February 3, with 154,000 tons of Prudhoe Bay crude oil. Heavy swell prevented offloading into a barge or flexible container until 0800 the next morning. Conditions were such as to allow offloading from then until 0800 February 5, when the vessel began to break up. Once the vessel began to disassemble and submerge, pumping operations had to be discontinued because of danger to the response team. Therefore, the amount of oil available for pumping is that shown in Figure 4-1 in the 48 hours between 0800 February 3 and 0800 February 5. During this period some 30,000 of the original 154,000 tons were lost. If the loss rate were independent of the pumping rate, and if it were desired to empty the vessel by 0800 February 5 (before breakup started), then an average pumping rate of 796,000 gallons/hour would have to have been achieved. From Section 6, it is seen that the ADAPTS pumping rate for Prudhoe Bay crude at 50°-80°F is about 1600 gpm., which means that 8.3 ADAPTS units (double stage) would be required, on the average, to be operating simultaneously for 48 hours. If each unit can be operated 18 out of every 24 hours, to allow for set up, and reset up on new tanks, then about 11 ADAPTS and spares would have to be delivered in operating order to the vessel.

Oil storage is assumed to be accommodated by the POHSSC system for the first 30 hours. In that time each ADAPTS would have offloaded 2,880,000 gallons, and 8.3 units would have offloaded about 24 million gallons. These can be contained in about 97 of the Type OW POHSSC. Each operating ADAPTS would require about 11.7 Type OW storage containers, on the average, over the 30 hours. This implies a new storage unit every 2.5 hours. It appears, then, that a technique would be required to change the containers with a minimum of down time. A down time of 30 minutes per change seems reasonable. The time to change containers might be substantially reduced if a Y-coupling, with valves in each of the arms, were employed. This would allow one container to be removed and replaced while the other is being filled.

The filling of flexible containers in heavy onshore swells from a stranded vessel, such as is being considered here, would be exceedingly risky because of the proximity of nearby submerged rocks. It is almost imperative to moor these containers well offshore of the stranded vessel and to feed them via floating hose. (The 1600 gpm pumping rate allows for 300 feet of hose.) The Type OW POHSSC are themselves about 300 feet long. If the PACIFIC PIGEON is 1000 feet long, with only the starboard side accessible, then the 8 operating pumps would be, on the average, about 125 feet apart. (See Figure 10-1.) It appears that attaching and removing the containers would be difficult because of the confined space between the extended bags, particularly if continuous operation via a Y coupling were desired. Space must also be allowed for the moorings at both ends of the containers. The handling of these storage containers would probably be the most difficult aspect of the offloading operation.

A time-line of the offloading requirements for PACIFIC PIGEON is given in Figure 10-2.

Scenario B

Offloading cannot commence on the UNIVERSAL WONDER until the fire is extinguished, which occurs at 1000 July 2. At that time some 40,000 tons (12.3 million gallons) will have leaked from the

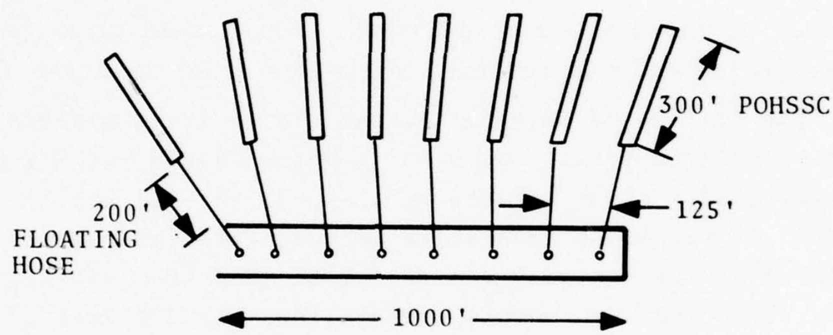


FIGURE 10-1 GEOMETRY OF OFFLOADING, PACIFIC PIGEON

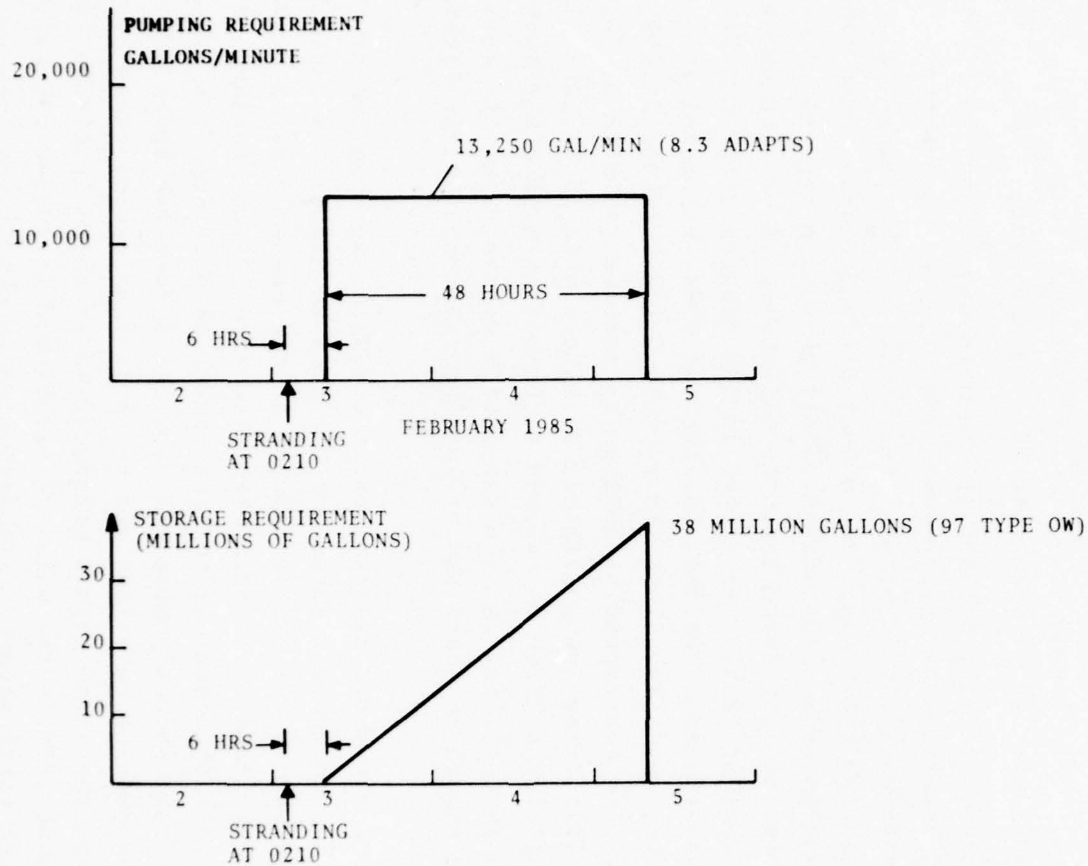


FIGURE 10-2 OFFLOADING REQUIREMENTS FOR PACIFIC PIGEON

vessel, and 68,000 tons (21 million gallons) will have burned. This leaves approximately 227,000 tons (69.9 million gallons) on board at 1000 July 2, leaking at the rate of approximately 930 tons per hour (286,000 gallons per hour). This leak rate drops constantly to about 200 tons per hour (61,600 gallons per hour) at 1000 July 7, when the vessel is sunk with 171,000 tons of crude on board. (See Figure 4-2.) During this entire period, weather conditions are benign enough to allow offloading.

Before deriving offloading requirements for the UNIVERSAL WONDER, some further assumptions must be made. Since the UNIVERSAL WONDER would be sunk in the Gulf of Mexico on July 7 with its remaining cargo, any amount offloaded from sound tanks would merely reduce the amount of oil sunk with the vessel. Therefore, it is assumed that the offloading is carried out only on the leaking tanks. As stated in the scenario, the UNIVERSAL WONDER sustained a 100 foot hole on one side, extending into the waterline, which is assumed to rupture 2 tanks (about 24,000 tons total). The corresponding outflow is assumed to be about 20,000 tons. This agrees approximately with Reference 10-1, Table 16. The remaining outflow is assumed to come from nine other tanks damaged in the fire. At the conclusion of the fire, the vessel is safe enough to board and offloading commences on the leaking tanks.

With the above assumptions, the offloading requirement may be stated, in general terms, as the need to offload as rapidly as possible the 96,000 tons remaining in the eleven damaged tanks. The leakage rate at t hours after the fire is extinguished is (.93-t/144) thousands of tons per hour, as obtained from Figure 4-2. If the amount pumped off does not affect the leakage rate, then the pumping rate required to empty the leaking tanks in t hours and the total amount offloaded is as shown in Figure 10-3. The amount left in the water to be skimmed is 29,600,000 gallons, minus the total amount offloaded shown in the Figure. As in the case of the PACIFIC PIGEON, a pumping rate of 1600 gpm per ADAPTS unit (double stage) can be achieved because of the relatively low viscosity of Persian Gulf crude in the 60°-90°F range. At that

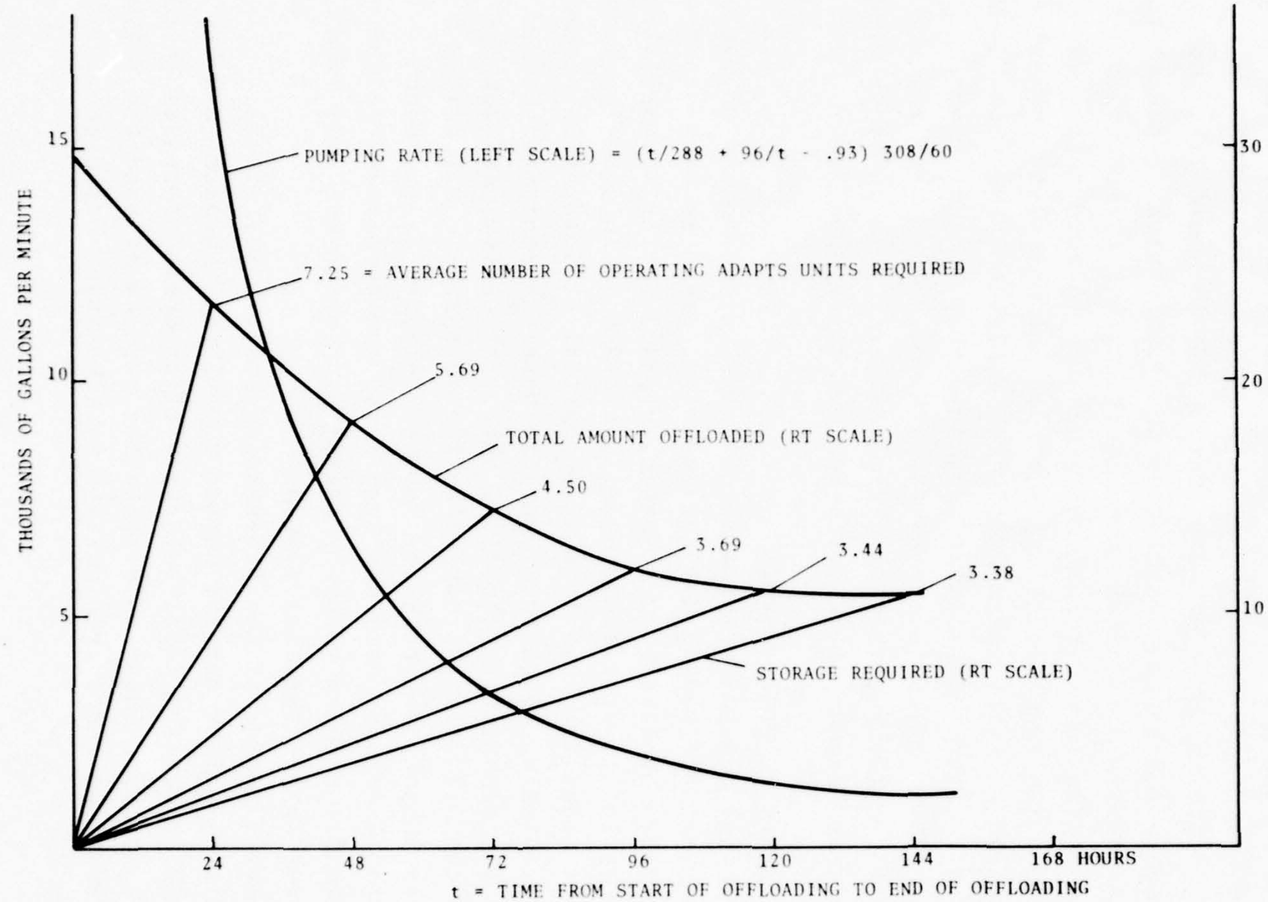


FIGURE 10-3 OFFLOADING REQUIREMENTS FOR UNIVERSAL WONDER

rate the average number of operating ADAPTS units required varies from 7.25 to 3.38, as shown in Figure 10-3. The wave heights of Figure 4-2 are such as to allow 97% loading of the POHSSC units. If Type OW are employed, each operating ADAPTS would fill one POHSSC every 2.9 hours, assuming no changeover time. Because the UNIVERSAL WONDER is floating free in relatively calm water at adequate depths (over 30 fathoms) it is feasible to moor seven or eight type OW barges alongside, extended out normal to the hull. Hard hull barges will not arrive until at least 8 and probably 24 to 36 hours after the collision, because they must be brought from Key West (75 n. miles to the east) or Miami (180-200 n. miles Northeast). Allowing that barge relief arrives in 36 hours gives a POHSSC requirement of 12 units per operating ADAPTS.

10.1.2 Skimming Requirements

Skimming equipment requirements will be determined on the assumption that offloading has not occurred, since in many cases offloading will not have been possible, or only partly accomplished. The assumption of no offloading will yield more information from the three scenarios than if full or partial offloading is assumed.

The skimming requirement and the baseline equipment needed to meet it, depend upon the size, shape, thickness, and composition of the oil slicks produced in the scenarios. Oil washed ashore is subject to secondary recovery efforts (i.e., beach and shore cleanup by hand and land-based equipment) and is not available for primary recovery (skimming carried out away from the shore) by the baseline system.

A brief review of the behavior of surface oil slicks (Appendix N) points out the numerous physical, chemical and biological processes involved. Very often these processes interact. In applying these effects to the problem at hand the following assumptions and approximations will be made, based on Appendix N:

(1) The general motion of an oil slick is approximately equal to the vector sum of the subsurface current, plus 3% of the wind speed.

(2) Advection of the slick by waves alone is poorly understood at present, and advection by waves and wind together even less well understood. Therefore, ad hoc assumptions must be made for each scenario.

(3) Slick spreading is assumed to occur approximately according to Figure 10-4 for the lighter components, which form a thin film of the order of 4×10^{-3}mm; after 2 to 3 days approximately 90% of the oil is assumed to be contained in layers of several millimeters thickness,* which occupy about 10% of the visible slick area. Spreading is superimposed on the general motion.

(4) Evaporation in all three scenarios will be taken as that for "average" crude, as given in Appendix N: 25% evaporated in 8 hours, 40% in 16 hours, about 50% in 5 days; at 20°C (68°F), sea state 2. These values are plotted in Figure 10-5

(5) The formation of a water-in-oil emulsion will be assumed to proceed similar to the experiments of Reference N-6. Specifically, the following viscosity-time values will be assumed, as shown in Figure 10-6.

* The thickness of these "pancakes" is apparently determined by the slick thickness at the time that evaporation and emulsification have removed the volatile, spreading fractions and rendered the central portion more viscous. As seen in the Table and in Figure 10-5, these two processes take about 1-2 days. Hence pancake thickness will be taken to be slick thickness on the 2nd day after the spill commences.

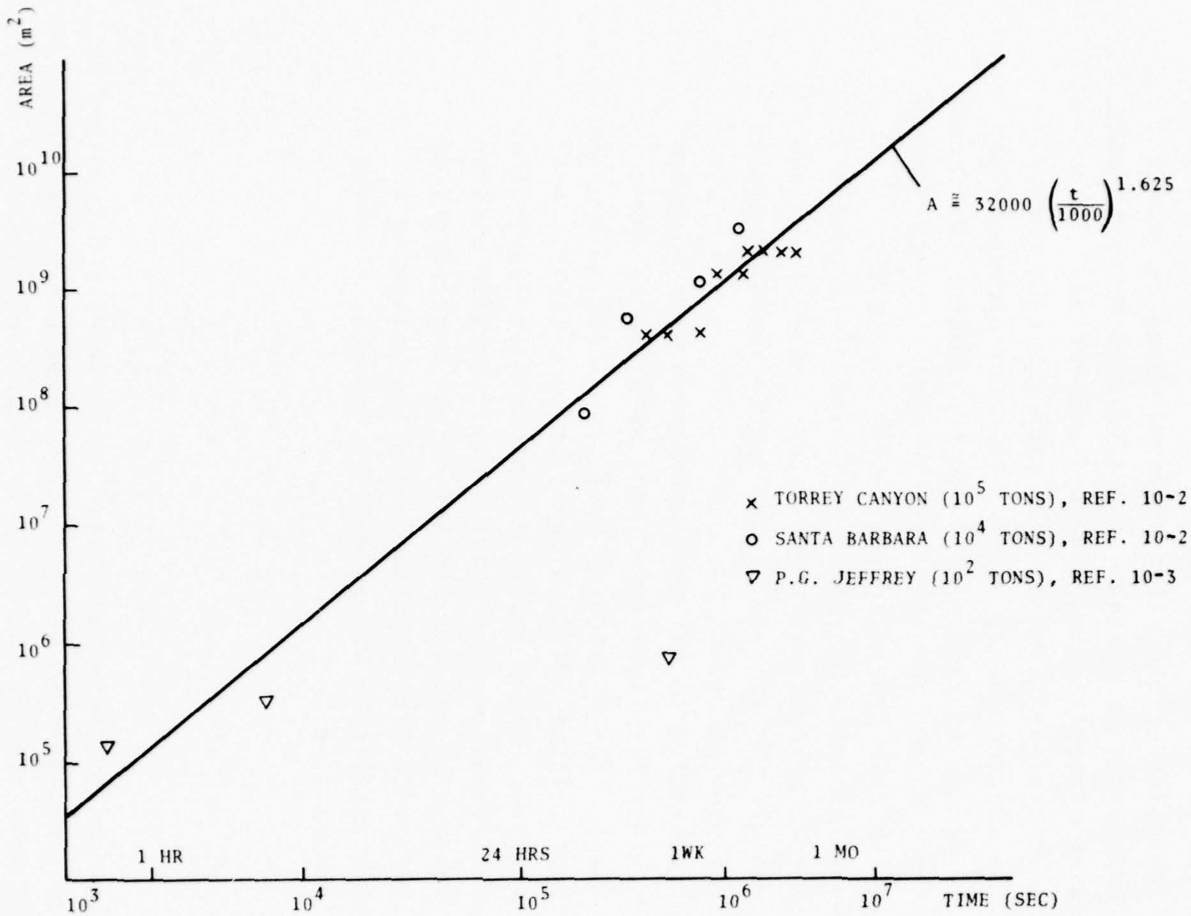


FIGURE 10-4 SLICK AREA VS TIME

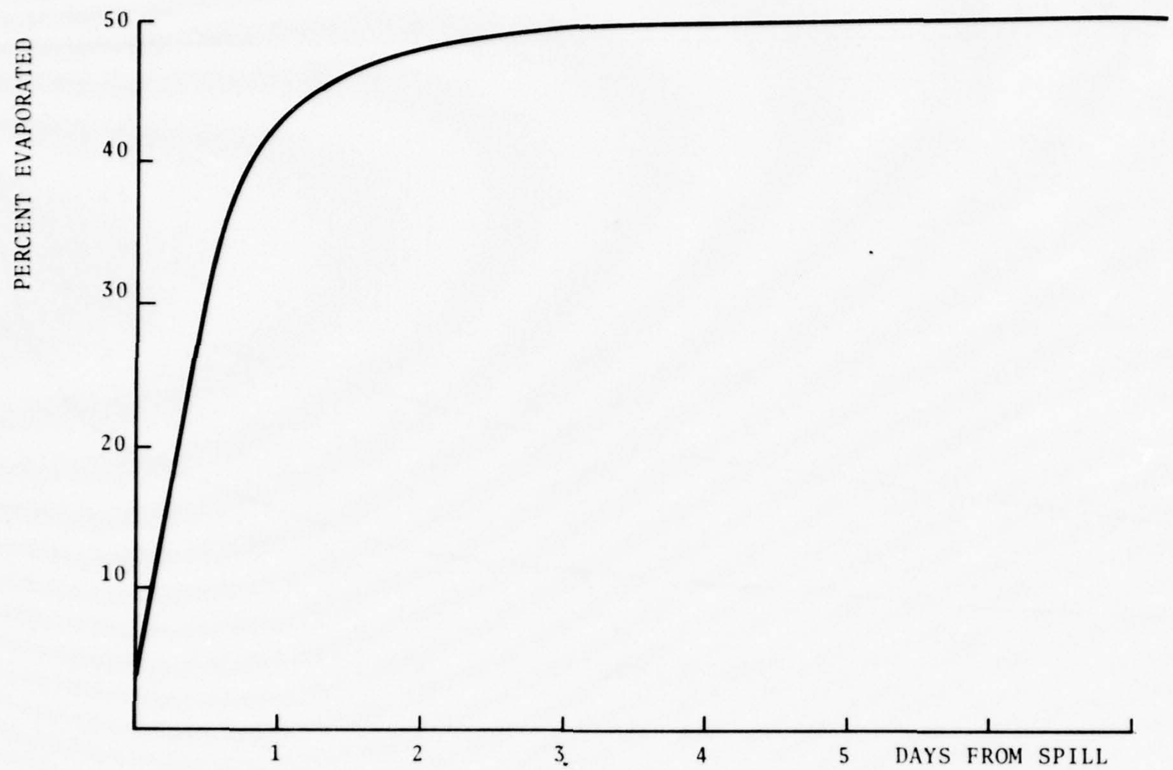


FIGURE 10-5 EVAPORATION FOR "AVERAGE" CRUDE

ADAPTED FROM REFERENCE N-6

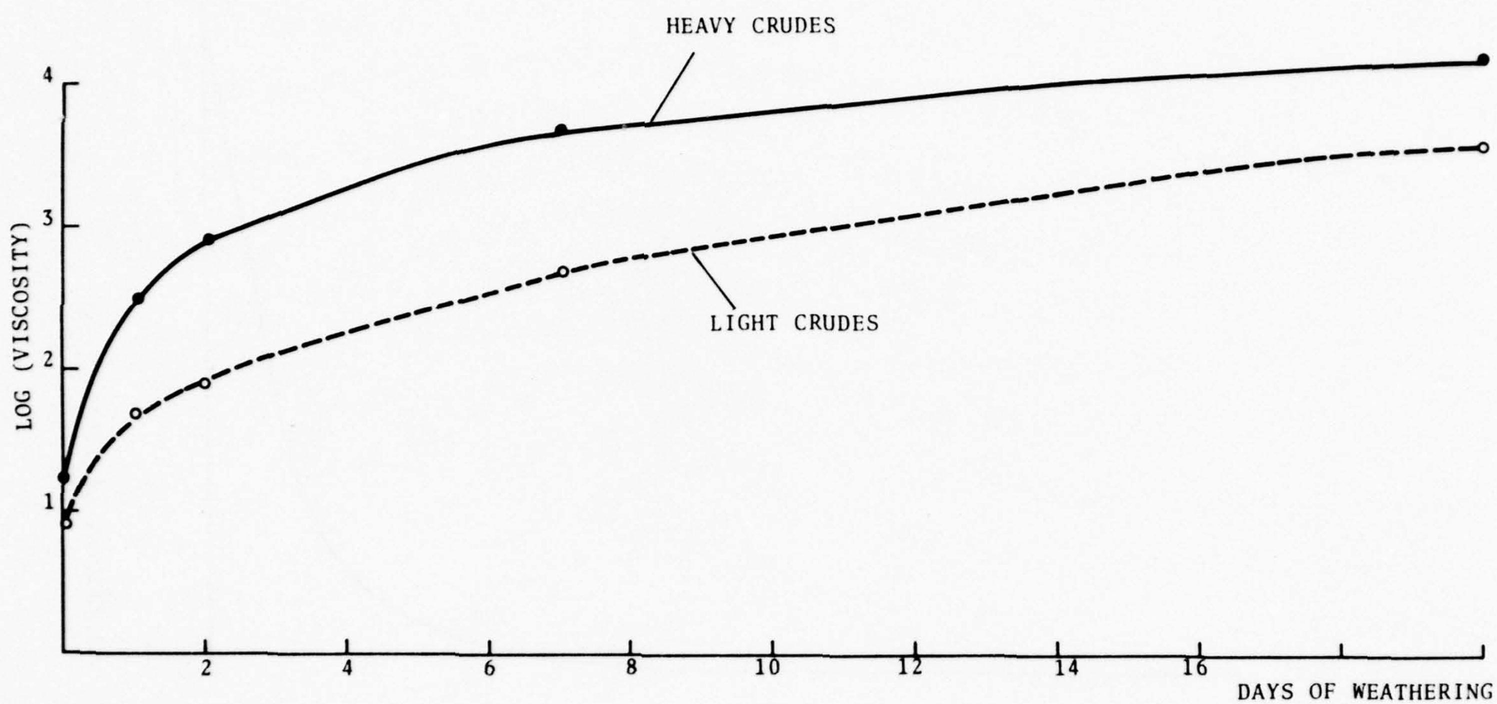


FIGURE 10-6 VISCOSITY VS WEATHERING TIME

Time from Start	Viscosity (centistokes) Heavy Crudes	Light Crudes
0	16	8
1 day	316	56
2 days	800	80
7 days	5,000	500
21 days	20,000	5,000

(6) The effects of dissolution, dispersion into the water, photo-oxidation, biodegradation and sedimentation will be ignored, as will all other effects not already mentioned.

The above assumptions provide a general framework for deriving skimming requirements. The three scenarios now will be treated in detail.

Scenario A - Skimming Conditions

Stranding occurs at the point of Cape Flattery, at 0210 Feb. 3, with seas 6-8 ft and onshore winds of 40 knots, gusting to 60. The outflow rate from time of stranding until breakup at 1000 Feb. 6, is taken from Figure 4-1 as 800 tons/hour, on the average.

At 0800 Feb. 3 about 4800 tons have been released and the slick is assumed to be one half mile long. From Figure 10-4, the slick area is approximately $5 \times 10^6 m^2$ or $1.46\ (n.mi.)^2$, which gives a "width" of 3 n. miles and an average slick thickness of .044 inches. The gravity-inertia phase of spreading must prevail in the vicinity of the vessel, while the gravity-viscosity phase probably prevails for the major part of the slick area. The winds average about 28 knots onshore during this 6 hour period (0210 to 0800 Feb. 3), giving a net slick motion of about 5.n. miles, more than enough to drive the slick 1 1/2 n. miles from Duntze rock to the tip of Cape Flattery.

At 1200 Feb. 3, approximately 8000 tons have been released; the slick is assumed to be about 5 n. miles by 1 n. miles, and its average depth is .021 inches. Because of the 8 ft. seas and 8 ft. swells, and high winds, the depth of the slick is probably greater along the shore itself. (The average area, according to Figure 10-4, however, is about 4 sq. n. miles, a difference that may be ignored).

By 0600 on Feb. 4, about 22,400 tons have been released; the slick area is assumed to be 10 n. miles by 1 n. mile (Figure 10-4 gives 6.3×10^7 m^2 or 18.4 sq. n. miles). The average slick thickness is .03 inches. Because of the drop in winds to 10 knots and waves to 4 ft., it is possible to commence skimming operations at this time. However, because the slick has been driven up against the coast, and extends about 1 n. mile to sea, not all of the slick is expected to be accessible for open water skimming. It is assumed that skimming operations closer than 1/2 n. mi. from shore would not be attempted. This gives about half of the slick (a strip 10 n. mi. by 1/2 n. mi.) available for skimming.

From 1000 Feb. 6 to about 1800 Feb. 6 the discharge rate is very high, and about 50,000 tons are released in the 8 hours due to the breakup, giving a total volume lost of 85,000 tons. This increase in volume will not immediately appear in slick dimensions.

By 0800 Feb. 8, 126 hours from the first leakage, the total volume released is about 90,000 tons. From Figure 10-4 the slick area is $7.1 \times 10^8 m^2$ or 207 square n. miles. This figure is too large for the situation along the Pacific Coast because of the presence of the shoreline, which acts as a barrier. A figure of 100 square n. miles for the Straits and one of 50 square n. miles along the coast will be employed instead. The coastal slick is assumed to be 50 n. miles long and 1 n. mile to sea, giving an average thickness of .012 inches, assuming it contains half the oil. The slick in the straits will be assumed to be 33 n. miles long and 3 n. miles wide, giving an average thickness, for its half of the oil, of .006 inches.

At 0600 Feb. 18, 364 hours from the start, essentially all of the 154,000 tons of oil has been released. The slick area, from Figure 10-4, is about 3.5 x $10^9 m^2$, or 1022 sq. n. miles. Again it is assumed that half of the oil and one-third the total slick area lies along the coast, and the other half of the oil and two-thirds of the total slick is in the Straits of Juan de Fuca. The coastal slick is 2 n. miles wide, 128 n. miles long, and .004 inches thick, on the average. Only the portion greater than 1/2 n. mi. from the coast is assumed to be accessible for skimming, where the average thickness is assumed to be .002 inches. The slick in the Straits is 512 sq. n. miles, 8 n. miles wide by 64 n. miles long, with an average thickness of .002 inches. Evaporation and pancaking have progressed extensively in the Straits.

During the entirety of Scenario A, the effects of evaporation, pancaking, and emulsification must be taken into account. Evaporation will reduce the volumes given above, and this is assumed to affect the slick thickness, but not the slick dimensions. The "pancaking" phenomenon described in Appendix N is assumed to occur in the Straits of Juan de Fuca, but not in the Pacific coast slick. Emulsification is assumed to occur in both slicks, but more in the one on the Pacific coast.

The results of allowing for the above three effects are shown in Table 10-1. In this Table, Q is the quantity of oil spilled, and Q' is the quantity remaining after evaporation is allowed for; h' is the slick thickness after evaporation is allowed for and measured (a) 1/2 the slick width from the shore, in the coastal slick, or (b) at the center of the pancakes in the Straits. The time, T', is hours from the time PACIFIC PIGEON arrived at Duntze rock.

The time employed to calculate evaporation loss is (T/2) while oil is still issuing from the vessel. Pancakes begin to form, by assumption, on the 2nd day as shown by the values of h' in the Straits of Juan de Fuca for hour 48 and after.

TABLE 10-1 SCENARIO A SLICKS

T' Hrs.	Q DWT	Q' DWT	L (n. mi.)	x	W (n. mi.)	x	h (in.)	h' in.	Viscosity cs	Wave Ht. ft.
PACIFIC COAST SLICK										
00	0	0	0.0	x	0.0	x	.000		16	6-8
6	2400	2160	1.5	x	0.5	x	.044	.040	39	6-8
10	4000	3280	2.5	x	1.0	x	.020	.016	79	8
28	11200	7400	5.0	x	1.0	x	.030	.020	251	4
48	19200	10950	10.4	x	1.0	x	.025	.014	800	2
88	42500	22500	32.0	x	1.0	x	.020	.010	1580	3
126	45000	23000	50.0	x	1.0	x	.012	.006	3160	3
364	77000	38500	128.0	x	2.0	x	.004	.002	11220	6
STRAITS OF JUAN DeFUCA SLICK										
0	0	0	0.0	x	0.0	x	.000		8	6-8
6	2400	2160	1.5	x	0.5	x	.044	.040	18	6-8
10	4000	3280	2.5	x	1.0	x	.020	.016	25	8
28	11200	7400	5.0	x	1.0	x	.030	.020	90	4
48	19200	10950	8.0	x	1.3	x	.025	.014	180	2
88	42500	22500	16.0	x	2.0	x	.020	.014	280	3
126	45000	23000	33.0	x	3.0	x	.006	.014	320	3
364	77000	38500	64.0	x	8.0	x	.002	.014	2000	4

The wave heights of Figure 4-1 apply to the coastal area. Waves under 5 ft. persist from 0600 Feb. 4 to 0000 Feb. 15, and from about 0600 Feb. 18 onward. Wave heights in the Straits of Juan de Fuca are assumed to be less than 5 feet from 0600 Feb. 4 onward.

Scenario A - Skimming Requirements

The quantities of oil available for skimming are plotted in Figure 10-7, while viscosities are shown in Table 10-1. Skimming rates are determined for the two baseline equipments under the conditions just obtained (Table 10-1 and Figure 10-7).

OWORS: The range of viscosities shown in Table 10-1 spans the operating range of the OWORS. If a slick thickness of 4" is maintained by the OWOCS then recovery rates would be in the 500-1,000 gallons per minute range, per unit, according to the data of Section 6. To keep pace with the leakage rate, minus evaporation rate, (dashed line in Figure 10-7) a total skimming capability of 70,840 gallons per hour must be achieved for each slick in the first 100 hours, and an average of about 20,500 gallons per hour for the next 300 hours. If a fixed rate is maintained for the entire 400 hours, then that rate must be about 30,800 gallons per hour per slick. After 360 hours the viscosity of the water-in-oil emulsion has reached 11,220 cs in the Pacific and the OWORS efficiency drops rapidly beyond that point. Hence the Pacific Ocean slick must be skimmed in about 400 hours.

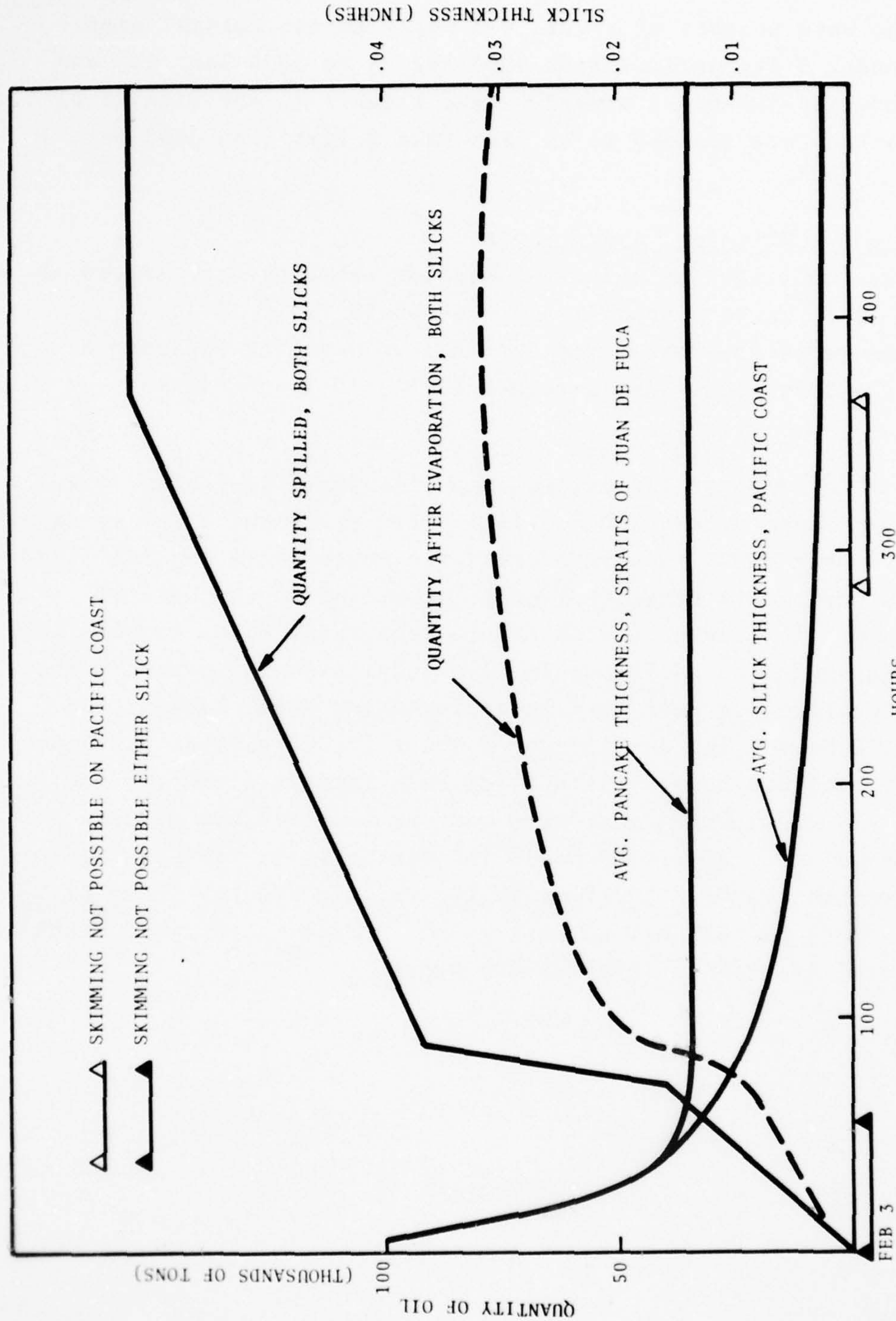


FIGURE 10-7 SLICK HISTORY FOR SCENARIO A

The 30,800 gallons per hour per slick will be taken as the operating requirement for Scenario A for the OWORS. In order to maintain a rate of 500 gallons per minute (30,000 gallons per hour) the OWORS requires a slick thickness of at least 1 inch. This is not available in either slick without the sweeping barrier (OWOCS) of the baseline system. However, the OWOCS cannot collect more than 300 gallons per minute in a .012 inch slick, such as would exist in pancake form in the Straits of Juan de Fuca. If pancakes do not form as on the coast, the slick would be 1/2 to 1/5 that of the Straits, with a corresponding drop in the barrier collection rate. Hence the limit of the OWORS is neither oil viscosity or slick depth at the disks, but the OWOCS collection rate. The latter is directly proportional to open water slick thickness, reaching 250 gallons per minute at .01 inch slick thickness, at a 1 knot sweep speed.

Given a peak rate of 300 gallons of oil per minute for the OWORS, operating inside a sweeping barrier, allowance must be made for (a) operating hours per day, (b) maneuvering efficiency. If one assumes (a) is 12/24, and (b) is 50%, it follows that in order to collect 30,800 gallons per hour, one requires

$$\frac{30,800}{300 \times 60 \times (12/24) \times .50} = 6.8 \text{ units}$$

per slick, plus spares. If the 6.8 units is rounded to 7, and 1 spare is adequate, then 8 units are required for the slick in the Straits of Juan de Fuca.

A note must be added regarding maneuvering efficiency. Suppose the slick reaches an area of 120 sq. n. miles, and that 90% of the oil is in pancakes of .01 inches thickness. Then the pancakes will cover about 60 sq. n. miles, or half of the total slick area. Hence a sweep will yield about 50% efficiency, even without maneuvering. If the pancakes are large, maneuvering can increase the efficiency above 50%. Whether these theoretical efficiencies can be achieved in practice is not known.

When attention is directed to a slick of less than .01 inch thickness, such as is assumed for the coastal area, it is seen that the number of units required to achieve a given recovery rate increases inversly with the thickness. Thus as the coastal slick thickness in Figure 10-7 drops with time to, say, 1/3 that of the Straits, 3 times as many OWORS/Barriers will be required to achieve the required 30,800 gallons per hour recovery rate. This appears to be approximately the proper ratio in the time 60-400 hours in Figure 10-7, and hence the nominal requirement for the Pacific Ocean slick will be taken to be 23 OWORS with associated Barriers (3x6.8+spares). The number of units that can be deployed simultaneously is limited by numerous factors, however, in addition to cost:

(1) Availability of tow vessels
(2) Availability of trained personnel
(3) Slick geometry
(4) Proximity of the shoreline

These factors make it difficult to determine whether the 23 units could work effectively in the area.

OWOCRS (Skimming Barrier): The skimming barrier is subject to the same collection rate limitation as the barrier alone, i.e. 250 gallons per minute with a .01 inch slick for a 1 knot speed and 400 foot aperture. (Neither speed nor aperture offer much possibility of increase, at the present state-of-the-art.)

In addition to the collection rate limitation, the OWOCRS is limited by pumping rate and recovery efficiency as shown in Figure 10-7b. The nominal pumping rate is 600 gallons per minute, and a 50% recovery efficiency might be expected according to the OHMSETT tests (Table 6-6). These tests were conducted with SAE 30 equivalent oil and Number 2 fuel oil, however. The "chocolate mousse" of Scenario A is much more viscous, and the recovery efficiency and recovery rate for such an emulsion are not established. Allowing a 50% recovery efficiency and a 600 gpm pumping rate brings the oil recovery rate of the pump and

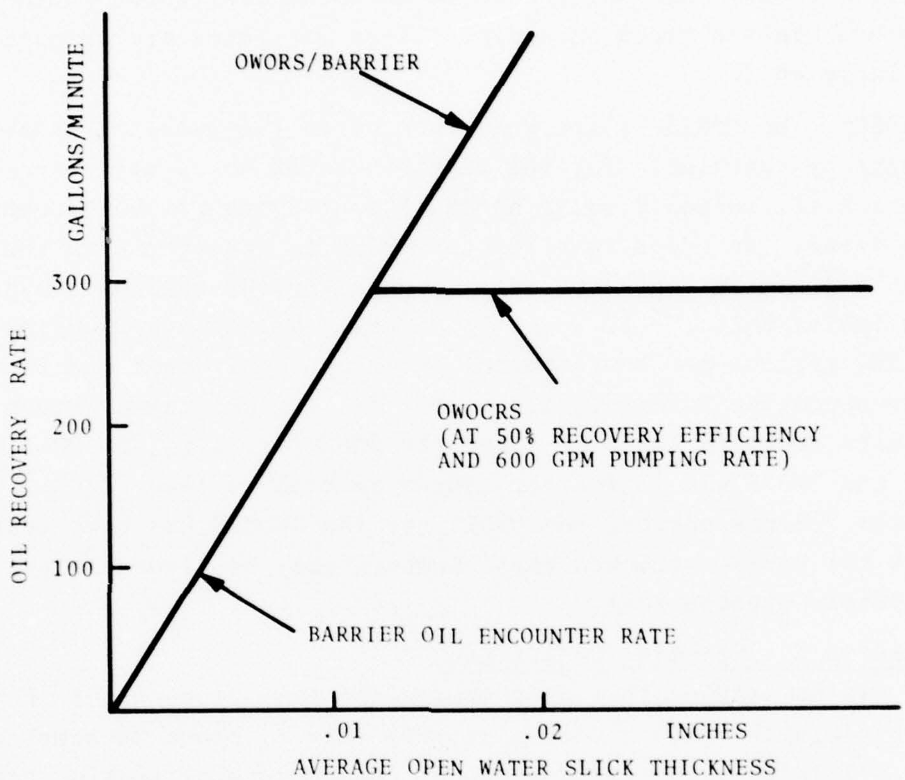


FIGURE 10-7b. OIL RECOVERY RATE VS SLICK THICKNESS

weirs to 300 gallons per minute, which matches the barrier sweep rate in a .012 inch slick. Thus the OWOCRS has performance equivalent to the OWORS operating within the same barrier. Hence the same number of units (8) would be required to handle the slick in the Straits of Juan de Fuca, and 23 to handle the slick on the Pacific Coast, assuming the above performance figures could be achieved in the given scenario. These estimates are summarized in Table 10-2.

POHSSC: The POHSSC's are conceived of in the present scenario as emergency containers for the first 18 to 30 hours of the response, i.e., until suitable local hardhull containers can be brought to the scene. In order to allow the OWOCS to maneuver with the work boat and bag attached the type F barge (50,400 gallons nominal; see Tables 6-11., - 12., and 13.) should be employed. Using the 30,800 gallons per hour nominal skimming requirement and the 30 hour operating interval, and an 85% filling efficiency gives the results shown in Table 10-2 for the POHSSC's, i.e., 24 POHSSC's for the OWORS and 43 for the OWOCRS in each of the slicks. Since neither the OWORS nor the OWOCRS has been tested with the POHSSC attached these numbers must be viewed at present as purely hypothetical.

Scenario B - Skimming Conditions

It is assumed that no skimming can take place until the fire is extinguished,which occurs at 1000 July 2, about 26 hours after the collision. At that time about 40,000 tons of Arabian crude have entered the water; oil continues to issue from UNIVERSAL WONDER at the rate (.93 - t/144) thousands of tons per hour, where t is hours after the fire is extinguished. Winds are from the east, in general, at about 10 knots, which moves the slick to the center of the Gulf of Mexico at about .3 knots.

The total amount spilled from UNIVERSAL WONDER and the amount left after evaporation are shown in Figure 10-8. The amount left after evaporation was obtained by machine computation by assuming a first-order evaporation process (a fixed fraction of all remaining volatile components evaporates per hour) with a time constant of 1/2 day, obtained from Figure 10-5. The volatile components

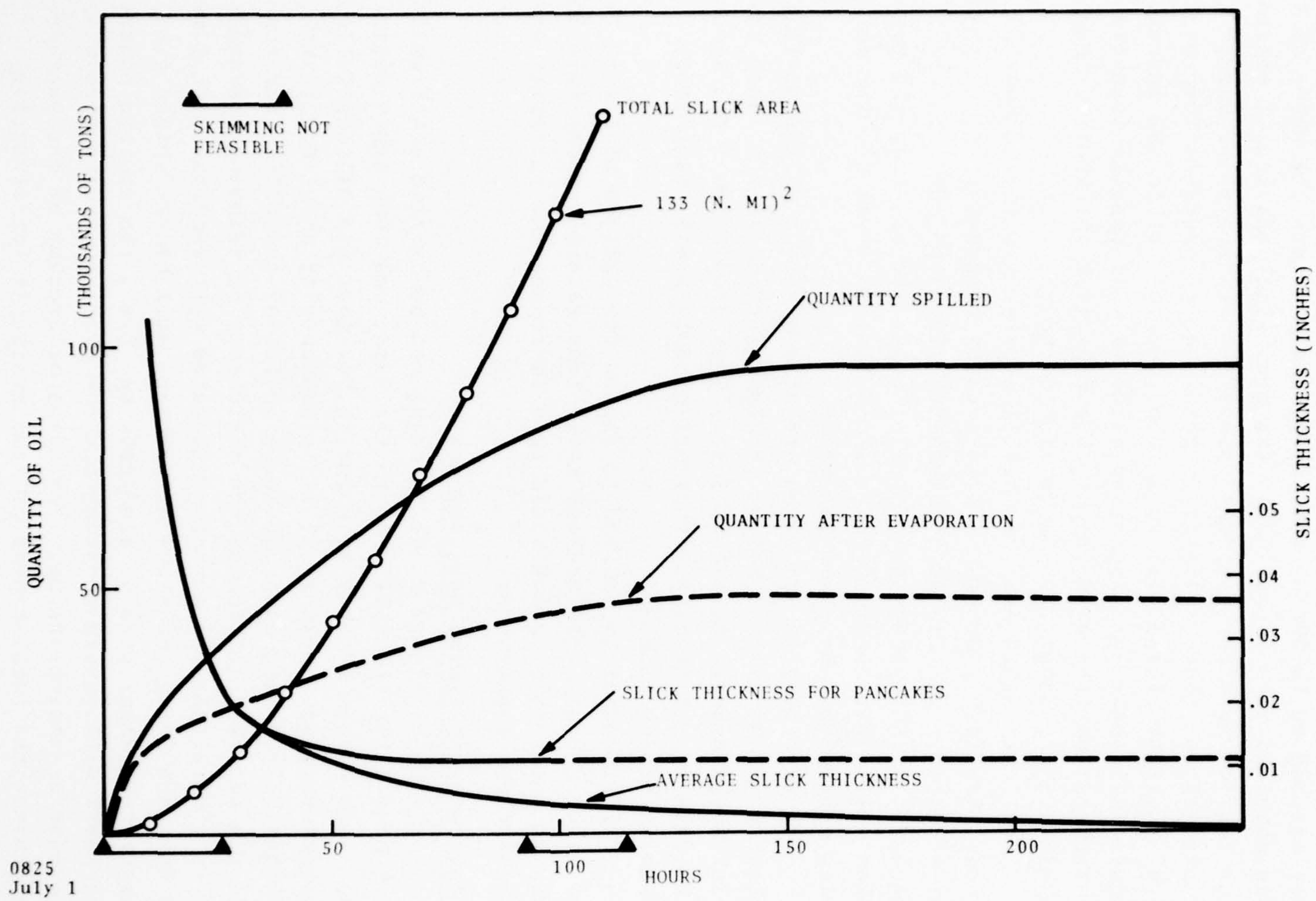


FIGURE 10-8. SLICK HISTORY FOR SCENARIO B

were assumed to be 50% of the crude, which enters the water at the rate obtained from Figure 4-2. The mean slick thickness, obtained from the volume after evaporation and the slick area of Figure 10-4, is also shown. Once again it is seen that if pancakes form at 2 days, their thickness will be in the range of .01 to .02 inches. Figure 10-8 shows .012 inches at 48 hours. If pancake formation is ignored (not the assumption) then the slick thickness is seen to diminish to about .005 inches in 100 hours.

The total slick area reaches 133 sq. n. mi. in 100 hours. It is likely that it has broken up into several components, as given in the scenario. If all the volume after 100 hours consists of pancakes, at an average thickness of 0.01 inches, then the pancakes will cover about 60 $(n.mi.)^2$ of the 133 $(n.mi.)^2$, the rest being covered by very thin oil films.

The wave heights and winds are at low enough values so that skimming may be carried out up to about 0500 on July 5, when wave heights again begin to exceed 5 ft. They drop below 5 ft. about 1200 July 6. It is likely that all of July 6 will be lost to skimming set-up time.

Oil viscosity is assumed to follow the pattern of Figure 10-6 for light crudes. The average water temperature for the Gulf in July is about 86°F, which would tend to reduce the viscosity and increase the evaporation.

Scenario B - Skimming Requirements

As seen in Figure 10-8, skimming can be carried out from the 26th hour after the collision to the 93rd, and then again after the 115th hour. A total of about 48,000 tons (15 million gallons) must be removed. Most of it is in pancakes of about 0.012 inch thickness, covering about 60 sq. n. miles of the Gulf. The number of such pancakes influences the efficiency of skimming operations. It is likely that the number of pancakes will increase with time, so that the 60 sq. n. miles of pancakes will become spread over a larger and larger area as time goes on, i.e., the average pancake thickness will remain constant but the average pancake size will decrease as they break up. The speed of breakup of the pancakes determines the total amount of time available for effective

skimming . It is assumed that large pancake areas will be available until the storm of July 5, after which they will have been largely dispersed. Therefore, the time from the 26th hour to the 93rd hour is the prime skimming time. To skim all 48,000 tons in these 67 hours requires an average recovery rate of 220,000 gallons per hour. This must be acquired while the slick area goes from about 15 $(n.mi.)^2$ to about 110 $(n.mi.)^2$, with about 60 square n. miles of .012 inch pancakes breaking away after about thirty hours. The average slick thickness drops from about .022 inches at hour 26 to about. 006 inches at hour 93.

The requirements for the baseline equipment in Scenario B, presented in Table 10-3, are now discussed.

OWORS/Barrier: The oil viscosity can be expected to increase from about 56 cs to 400 cs in the skimming time. The OWORS reaches peak efficiency at about 1000 cs. Nevertheless the recovery rate is limited by slick thickness, rather than viscosity, and as in Scenario A, the OWORS must be operated within a barrier. The oil encounter rate of the barrier is the limiting factor in OWORS operation, as in Scenario A. In fact it is seen that the average slick thickness, pancake thickness, and slick area are similar to that in the Straits of Juan de Fuca in Scenario A. The ratio of pancake area to total slick area reaches about 0.5 at about the 100th hour, suggesting that a maneuvering efficiency of 50% is achievable, which percentage will be assumed. A utilization factor of 12 hours per day will again be employed. The maneuvering efficiency and utilization may be optimistic considering the frequency of bag changes that will be seen to be required.

OWOCRS: The recovery rate for this equipment is essentially the same as for the OWORS operating within a similar barrier, since the barrier collection rate is the limiting factor in both cases. One major difference that emerges is in the number of POHSSC's required: the assumed 50% recovery efficiency of the OWOCRS means that it fills the POHSSC twice as fast as the OWORS.

It is apparent from this scenario, as from the previous, that the OWORS is mismatched to the open-water barrier by a factor of about 2. A disc-type skimmer, with inherently high recovery efficiency, need not have an average recovery rate greater than 300 gal/min. to operate in the barrier. It appears that a unit of about half the capability would be more suited to operation in the 600 ft. barrier than the OWORS of the baseline. Alternately, a 1200 ft. barrier might be considered.

POHSSC: The requirement for type F units, given in Table 10-3, is substantial. In particular, the OWOCRS combination requires a new storage container about five times per day as was found in Straits of Juan de Fuca in Scenario A. If skimming is carried out only in the daytime, then this corresponds to a new container every 2.5 hours, which would make the 50% maneuvering efficiency difficult to achieve.

Observations: The number of units called for in Table 10-3 is substantially higher than in Scenario A even though the amounts of oil to be recovered and the unit capability are similar. The reason is the relatively short collection period, 67 hours, in Scenario B. The period is short because of the assumed storm on July 5, which comes only about three days after the end of the fire. As may be seen in the Section 5 on environmental conditions, the probability of the assumed wave conditions occuring during a 5 or 10 day skimming operation are not small. Hence the truncated skimming period is not considered unrealistic.

Resumption of skimming after the July 5-6 storm is not impossible. The larger pancake formations would most likely disappear in the storm, and the barrier would encounter, for most of the time, the average slick thickness shown in Figure 10-8 for the time after 115 hours. This average thickness is about .004 inches and continuously drops off to about .002 inches at 200 hours due to spreading. The oil encounter rate of both OWORS and OWOCRS equipment would drop off from 300 gallons/minute before the storm to about 100 gallons/minute immediately after it. It would continue to drop, eventually to zero, because of spreading. Clearly,

if x percent of the required equipment were deployed before the storm then 1 - x/100 of the oil would remain to be recovered after the storm. Moreover the recovery rate per unit would be, on the average, only about 1/6 of that before the storm, due to spreading. Thus it would take at least Tr hours,

$Tr = 67 + 67\ (1-x/100)/(1/6\ \frac{x}{100})$, for the complete recovery.

Number of Units	x	Tr
54 units	100%	67 hours
40	75	201
27	50	469
13	25	1273
5	10	3685

The above serve as a lower limit on the actual time required to recover the oil because they do not allow for thinning of the slick due to the recovery effort itself.

Scenario C - Skimming Conditions

The 3.5 million gallon spill postulated in Scenario C differs from the previous two in that the volume of oil released is much less and the release time much greater than at Cape Flattery or in the Straits of Florida. Once again it is assumed that an "average" crude is spilled, consisting of 50% volatile compounds, which evaporate according to a simple first-order process with a 1/2 day time constant.

The slick area as a function of time given in Figure 10-4 is a rough estimate, having only one set of samples in the lower volumes (100 tons, Reference 3, Jeffrey, 1972). It is likely that the low discharge rates of the wells (13.6 tons per hour) will produce a smaller slick area at a given time than a sudden discharge of the entire 10,700 tons (the amount that comes from the wells over the 30-day period). Hence the slick area as a function of time given in Figure 10-4 is reduced by 1/2 for the purposes of this scenario.

The wave heights given in Figure 4-3 exceed five feet three times during the discharge, and once again about 5 days after the wells are sealed off. Winds exceed 20 knots about half of the time shown in Figure 4-3.

The quantity discharged, quantity left after evaporation, slick size and average slick thickness for Scenario C are shown in Figure 10-9. Because of the relatively slow discharge, wind and waves spread out the oil to a thin layer before pancakes can form. If these are taken to begin about the 2nd day(say 50 hours) it can be seen from Figure 10-9 that they would be about .0005 inches thick, much less than in the case of the previous two scenarios. For the sake of concreteness it will be assumed that the volume after evaporation is contained in pancakes of thickness .0005 inches. They would cover only a fraction of the total slick area shown in Figure 10-9.

Scenario C - Skimming Requirements*

As discussed in the previous two scenarios, the OWORS and OWOCRS have recovery rates limited by the barrier sweep speed and aperture. The 600' barrier encounter rate is approximately 250 gallons per minute for a .01 inch slick. For thicker slicks the recovery rate increases for the OWORS/Barrier up to the limits of the OWORS (about 500-1000 gallons/minute for 1" to 5" slicks at the disks). The OWOCRS, however, is limited even in slicks thicker than .01 inch by the recovery efficiency and pumping rate. (See Figure 10-7b). Obviously in this Scenario, the equipment is operating in the region very close to the origin, because of the .0005 inch slick projected to occur. In fact, at .0005 inch thickness, the encounter rate is only 12 gallons/minute. At this rate, it would take about 200 skimmer days to recover the total 3.5 million gallons spilled, not allowing for maneuvering efficiency and utilization factor.

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*The assumption is made here that all pollution control gear provided for on the platform has been lost in the collapse and that USCG equipment is required.

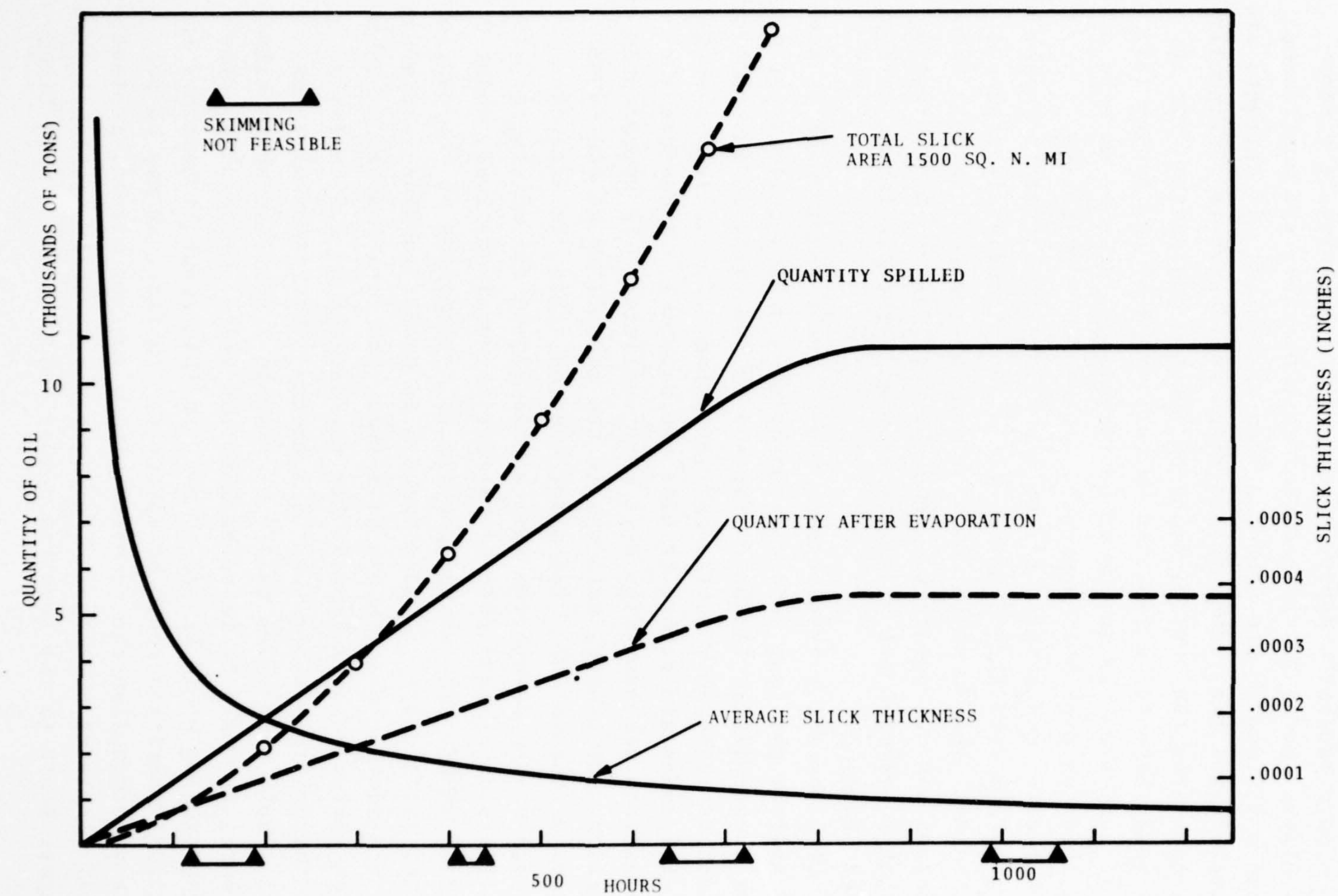

FIGURE 10-9. SLICK HISTORY FOR SCENARIO C

A more realistic approach than direct sweeping is a semi-encirclement mode, in which one or more barriers are positioned around a 180 degree arc downwind from the wells. If currents are greater than 1 knot, then the barriers would have to continually back away from the source, being positioned downstream from it. They would have to be replaced by barriers that had backed far enough away from the source to be receiving little or no more oil. With this conveyor belt approach, a reasonable objective is to recover essentially all of the oil emitted from the wells as it comes out over the 30 days. (It is not immediately apparent how the oil flow at night would be made up the next day, if night operation was not possible. Hence we shall assume that night operation is carried out by lights from adjacent platforms, or from moored vessels).

With the above assumptions, the recovery requirement is simply 4200 gallons per hour before evaporation and 2100 gallons per hour after evaporation. If the distance from the wells to the recovery devices is reasonably short, say less than .25 n. miles, then little oil will evaporate before it hits the barriers. Therefore the 4200 gallons per hour figure is more realistic. It corresponds to 70 gallons per minute, well within the capability of one OWORS/ Barrier or one OWOCRS. The major concern, then, is adequate coverage of the downstream semi-circle around the wells. At .25 n. miles radius, 4800 feet of barrier is required, i.e., about 8 units of OWOCS. The second concern is replacement of the barriers as they drift away. A third concern is proper mooring. Assuming that the mooring problem can be solved, the total number of units may be estimated as follows: Let the current be 1.5 knots, so that the drift is 1.5 - 1.0 = 0.5 knots. The 1/4 n. mile semi-circle would then widen to 3/4 n. mile in 1 hour, at which time the barriers would be towed back to the 1/4 n. mi. radius. The average radius would be 1/2 n. mi., so that about 16 barriers in continual operation would be adequate. In fact, it may be possible to accomplish the recovery with a quarter circle, instead of a half circle of coverage. Therefore the 16 units are considered an upper limit to the required number, and 8-10 as a more likely

figure, even if currents are 1.5 knots. If the current is below the critical speed, then 4 to 8 OWORS/Barriers or OWOCRS would be adequate.

The POHSSC requirement is obtained for this Scenario by dividing the outflow rate, 4200 gallons/hr., by the type F capacity, 42,800 gallons, to obtain .11 POHSSC per hour, for the OWORS/Barrier (90% recovery efficiency) and .19 POHSSC per hour for the OWOCRS. Over 30 hours, a total of 3.3 (i.e. 4) POHSSC would be required for the OWORS and 5.7 (i.e. 6) for the OWOCRS.

The skimming requirements for Scenario C are summarized in Table 10-4. A semi-circle of 1/4 n.mi. is assumed, current less than 1 knot. The recovery would be suspended during periods of adverse weather, a total of 22% of the time.

Observations: If currents remain less than the critical value then this Scenario presents relatively few uncertainties, aside from the possibility of fire or explosion. On the other hand, if currents exceed the critical value for the barrier, then, although the equipment requirements are still reasonable, the operational difficulties are greater than in either of the other two scenarios. In particular, a method must yet be worked out and tested that would allow 8 barriers, sixteen tow boats, 8 pump floats, 8 attendant boats, 8 flexible containers and all the connecting hose to operate in synchronism with the current in a semi-circular area of about one square mile. At the present level of planning and experimentation this operation must be considered impractical.

It should also be noted that the well outflow rate may be increased by a factor of thirty (30) to 3,000 BBL per hour, (400 tons/hr.) before the recovery rate of either OWORS or OWOCRS is exceeded, in the stationary semi-circular configuration.

AD-A070 815 TRANSPORTATION SYSTEMS CENTER CAMBRIDGE MA F/G 13/2
DEPLOYMENT REQUIREMENTS FOR U.S. COAST GUARD POLLUTION RESPONSE--ETC(U)
FEB 79 J BELLANTONI, J GARLITZ, R KODIS
UNCLASSIFIED TSC-USCG-79-2-1 USCG-D-14-79-1 NL

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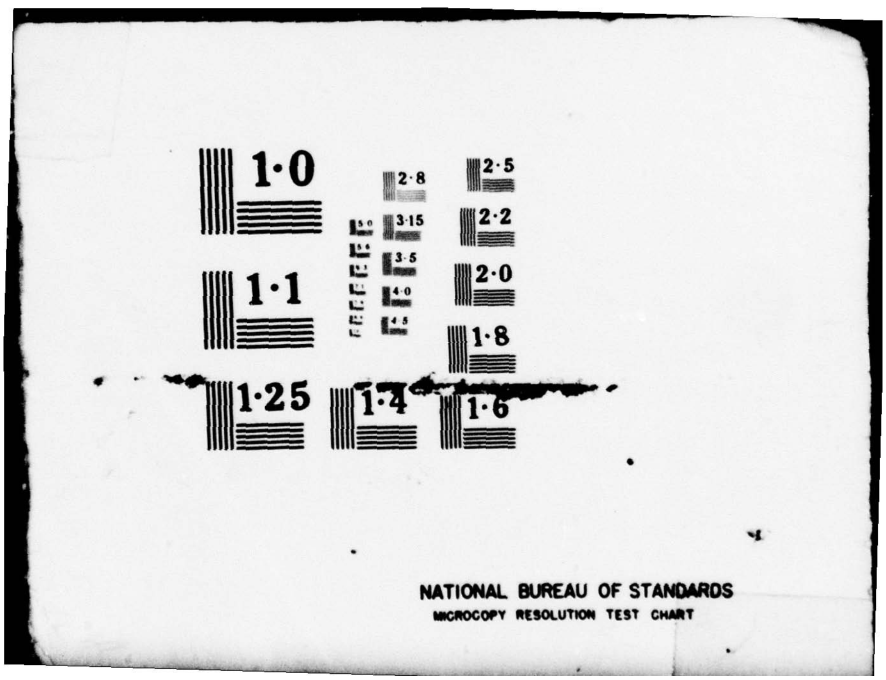
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TABLE 10-2 SCENARIO A SKIMMING REQUIREMENTS

	Straits of Juan de Fuca	Coast	Units
Total to be Recovered*	40,000	40,000	Tons
Recovery Period	400	400	Hours
Average Recovery Rate Req'd.	30,800	30,800	Gallons/Hr.
Average Slick Thickness	.012		
OWORS/Barrier			
Oil Encounter Rate, Max/Unit**	300	100	Gal./Min.
Maneuvering Efficiency	50	50	Percent
Utilization	12	12	Hours/Day
Average Recovery Rate/Unit	108,000	36,000	Gal./Day
Average Number of Units in Operation over Recovery Period	6.8	20.4	Units
Number of Units on Scene	8	23	Units
Recovery Efficiency	90	90	Percent
Mixture Collection Rate per Unit	83	28	Gal./Min
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	2.8	.93	POHSSC's
POHSSC per Day for all Units	19	19	POHSSC
POHSSC for 30 Hours, all Units	24	24	POHSSC's
OWOCRS			
Oil Encounter Rate, Max/Unit	300	100	Gal./Min.
Maneuvering Efficiency	50	50	Percent
Utilization	12	12	Hrs./Day
Average Recovery Rate/Unit	108,000	36,000	Gal./Day
Average Number of Units in Operation over Recovery Period	6.8	20.4	Units
Number of Units on Scene	8	23	Units

TABLE 10-2 (Concluded)

	Straits of Juan de Fuca	Coast	Units
Recovery Efficiency	50	50	Percent
Mixture Collection Rate/Unit	150	50	Gal./Min.
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	5.0	1.68	POHSSC's
POHSSC per Day, all Units	34.3	34.3	POHSSC's
POHSSC for 30 Hours, all Units	42.9	42.9	POHSSC's

* Evaporation allowed for.

** A "Unit" refers to one complete skimming apparatus.

TABLE 10-3 SCENARIO B SKIMMING REQUIREMENTS

	OWORS/ BARRIER	OWOCRS	UNITS
Total to be Recovered*	48,000	48,000	Tons
Recovery Period	67	67	Hours
Average Recovery Rate Req'd.	320,000	220,000	Gal./Hr.
Average Slick Thickness	.022-.006	.022-.006	Inches
Average Pancake Thickness	.012	.012	Inches
Oil Encounter Rate, Max./Unit**	300	300	Gal./Min.
Maneuvering Efficiency	50	50	Percent
Utilization	12	12	Hrs./Day
Average Recovery Rate/Unit	108,000 75	108,000 75	Gal./Day Gal./Min
Average Number of Units in Operation over Recovery Period	48.9	48.9	Units
Number of Units on Scene	54	54	Units
Recovery Efficiency	90	50	Percent
Mixture Collection Rate/Unit	83	150	Gal./Min.
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	2.8	5.0	POHSSC's
POHSSC per Day, all Units	137	246	POHSSC's
POHSSC for 30 Hours, all Units	171	308	POHSSC's

* Evaporation allowed for.

** A "Unit" refers to one complete skimming apparatus.

TABLE 10-4 SCENARIO C SKIMMING REQUIREMENTS

	OWORS/ Barrier	OWOCRS	UNITS
Total to be Recovered*	3,500,000	3,500,000	Gallons
Recovery Period	850	850	Hours
Average Recovery Rate Req'd.	4,200	4,200	Gal./Hr.
Oil Encounter Rate, Avg. Per Unit**	8.75	8.75	Gal./Min.
Maneuvering Efficiency	100	100	Percent
Utilization	24	24	Hrs./Day
Average Recovery Rate/Unit	8.75	8.75	Gal./Min.
Average Number of Units in Operation over Recovery Period	8	8	Units
Number of Units on Scene	10	10	Units
Recovery Efficiency	90	100	Percent
Mixture Collection Rate/Unit	9.7	17.5	Gal./Min.
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	.33	.59	POHSSC's
POHSSC per Day, all Units	2.6	4.7	POHSSC's
POHSSC for 30 Hrs, all Units	2.9	5.9	POHSSC's

* Without evaporation.

** A "Unit" refers to one complete skimming apparatus.

10.1.3 Summary of Requirements

The amounts of baseline equipment required to respond to the three scenarios are summarized in Table 10-5. The numbers shown are for complete operating units, including reserve units at the scene. They assume 100% recovery and 100% offloading, except for the lower figure for offloading under Scenario B. When the per unit sizes and weights of Section 7.1 are applied to Table 10-5 the results are as given in Table 10-6.

When the number of units called for in the different scenarios, from Table 10-5, is compared to the total number of units determined for Configuration 5 in Table 9-14, one finds:

	Available in Configuration 5	Maximum Called for, Scenario X
ADAPTS	8	12, (Scenario A)
POHSSC, Type OW	42	97, (Scenario A)
OWORS/Barrier	219	54, (Scenario B)
OWOCRS	219	54, (Scenario B)
POHSSC, Type F		
for OWORS	331	171, (Scenario B)
for OWOCRS	662	308, (Scenario B)

Except for the ADAPTS and POHSSC called for to unload PACIFIC PIGEON in Scenario A, the equipment required for the Scenarios is available in Configuration 5. The unloading requirement for PACIFIC PIGEON, however, assumed a mooring configuration for the POHSSC Type OW that would be very difficult to achieve. It is likely that only about half as many containers could be moored in practice, thus limiting the number of pumps that can operate simultaneously and reducing the amount that could be offloaded. Considering the difficulty of employing 97 Type OW barges in the same operation, and the possible availability of hard-hull barges and/or tankers in the first 24 hours, it appears that this particular requirement can be reduced substantially without any probable impact on massive spill response effectiveness. The implications of such a reduction will be discussed in Section 11.

TABLE 10-5 BASELINE EQUIPMENT REQUIRED FOR SCENARIOS A, B, C

	SCENARIO		
	A (1)	B (2)	C (3)
<u>Offloading</u>			
ADAPTS	12	5 to 9	-
POHSSC Type OW	97	42 to 90	-
<u>Skimming</u>			
OWORS/Barrier	8+23	54	10
OWOCRS	8+23	54	10
POHSSC Type F:			
for OWORS/Barrier	24+24	171	3
for OWOCRS	43+43	308	6

Notes:

(1) The two components given for skimming under Scenario A apply to the Straits of Juan de Fuca and the Pacific Coast, respectively.

(2) The lower figure for offloading in Scenario B achieves 34% offloading from the leaking vessel and the upper figure achieves 75% offloading.

(3) Offloading does not apply to Scenario C.

TABLE 10-6 EQUIPMENT WEIGHT, SIZE AND COST FOR SCENARIOS A,B, &C

	10^3lbs.	Cu. ft.	10^3dollars
SCENARIO A			
Offloading			
ADAPTS	72	2,400	720
POHSSC (Type OW)	1330	71,600	23,280
Recovery (OWORS)			
OWORS/Barrier	1030	64,170	28,020
POHSSC(Type F)	422	16,416	4,320
Recovery (OWOCRS)			
OWOCRS	590	34,100	5,425
POHSSC(Type F)	757	29,400	7,740
SCENARIO B			
Offloading			
ADAPTS	54	1,800	540
POHSSC (Type OW)	1230	66,420	21,600
Recovery (OWORS)			
OWORS/Barrier	1800	112,000	48,800
POHSSC(Type F)	1500	58,482	15,400
Recovery (OWOCRS)			
OWOCRS	1026	59,400	9,450
POHSSC(Type F)	2710	105,340	27,720

TABLE 10-6 (concl.)

SCENARIO C

	10^3 lbs.	Cu. ft.	10^3 dollars
Offloading			
ADAPTS	—	—	—
POHSSC (Type OW)	—	—	—
Recovery (OWORS)			
OWORS/Barrier	332	20,700	9,040
POHSSC(Type F)	26	1,030	270
Recovery (OWOCRS)			
OWOCRS	190	11,000	1,750
POHSSC(Type F)	53	2,050	540

10.2 LOGISTIC STRATEGIES

Several general strategies may be conceived of for delivering the required equipment to the debarkation point for a massive spill. Three were selected for detailed examination:

1. All Land: The equipment is moved from the land sites of Configuration 5 to the debarkation point by the trucks on which it is pre-loaded.
2. Land/Air/Land - Regional Collection: The equipment, pre-loaded on trucks, is moved to an airport that serves as a regional collection center for several sites. It is then flown to a suitable airport near the debarkation point.
3. Land/Air/Land-Local Collection: This is the same as 2., except that the equipment goes from the land site to a suitable local airport, rather than to a regional collection airport.

Strategies 2 and 3 apply also to Configurations 5a and 5b, in which the USCG air base equipment site would serve as one of the collection centers.

Implicit in all these strategies is the assumption that any additional equipment required to respond to massive spills would be located at one or more of the sites of Configuration 5, 5a or 5b. If the massive spill responses achievable under this assumption are inadequate, then the addition of sites to Configurations 5, 5a or 5b must be considered. Equipment delivery profiles are calculated for Port Angeles WA, Key West FL, and Atlantic City NJ, which are likely debarkation points for scenarios A, B, and C respectively. The profiles, consisting of capability delivered vs. time, are calculated for offloading and skimming.

In examining these strategies, the time-history of equipment delivery to the debarkation point will be compared with the oil release profile for each scenario. In order to estimate the delivery history it is necessary to make some simplifying assumptions. They will be discussed in the next subsection.

10.2.1 General Assumptions

It is assumed that all available land-based and air-based equipment will be delivered to the massive spill site, but that 20% of the water-based equipment will be retained for multiple spill coverage. The probability of two concurrent massive spills is low enough (about .01, as calculated in Appendix L) that only a fraction of the total response capability need be reserved. This fraction would serve primarily to allow for the possibility of a simultaneous non-massive spill occurring before the main portion of the equipment is returned from the massive spill debarkation site. Since only integral numbers of pumps, containers, and skimmers may be shipped, some arbitrary assignments were made for the equipment to be left behind. At the outset configuration capability levels were assumed from Tables 9-11 and 9-12. They were converted to units of equipment, using the baseline per unit capabilities of Table 9-13. When the reserve of water-based equipment is allowed for, the amounts available are as shown in Table 10-7 (only sites in the 48 states are considered to respond to the scenarios). Either the OWOCRS or OWORS/Barrier would be stored and employed in Configuration 5 at any one site. The weights corresponding to the equipment shown in Table 10-7 are given in Table 10-8.

It is assumed that the offloading equipment is delivered first, followed by the skimming equipment. In the most demanding scenarios, A and B, of Table 10-6, the OWORS/Barrier weight is approximately the same as the OWOCRS, when the POHSSC weight is included. In practice only one of the two systems will be deployed. From the standpoint of logistics, no substantial difference could be seen in the present study when the complete systems (including POHSSC) were considered. For delivery calculations, the OWORS/Barrier was employed.

For strategies 2 and 3 it is necessary to make assumptions regarding the number of aircraft available for pollution response duty. Since a spill of the order of 100,000 tons of oil in U.S. coastal water is likely to be a regional emergency, it is assumed that all USCG C130 aircraft, except a minimum required for search and rescue, would be made available. Based on 1977 deployments,

TABLE 10-7 UNITS OF EQUIPMENT AVAILABLE FOR MASSIVE SPILL RESPONSE (1)

		ADAPTS 2 Stage	POHSSC Type O	OWORS Barrier	POHSSC Type F	(2) OWOCRS	POHSSC (2) Type F
Philadelphia PA	L	1	1	1	1	1	1
Philadelphia PA	W	0	5	37	57	37	114
New Orleans LA	L	1	2	12	17	12	33
New Orleans LA	W	0	3	19	26	19	53
New York NY	L	1	1	5	5	5	10
New York NY	W	1	2	26	28	26	55
San Franscisco CA	W	1	4	11	17	11	34
Galveston TX	W	1	3	6	15	6	30
Los Angeles CA	L	1	1	2	6	2	11
Los Angeles CA	W	0	3	6	20	6	40
Pascagoula MS	W	1	4	6	14	6	28
Sabine TX	L	1	1	2	3	2	5
Sabine TX	W	1	2	9	12	9	24
Port Aransas TX	W	1	2	6	10	6	18
Boston MA	L	1	5	21	33	21	66
Portsmouth VA	L	1	1	2	4	2	7
Portsmouth VA	W	1	1	1	2	1	5
Seattle WA	L	1	2	3	5	3	9
Clearwater FL	L	1	2	8	11	8	20
Chicago IL	L	1	2	2	3	2	5

(1) 100% of land-based plus 80% of water-based units obtained in Tables 9-11 and 9-12.

(2) Either these units or the ones shown to the left under OWORS/Barrier, and POHSSC Type F would be deployed at any one site.

TABLE 10-8 WEIGHTS OF EQUIPMENT AVAILABLE FOR MASSIVE SPILL RESPONSE [1]
(THOUSANDS OF LBS)

		ADAPTS 2 Stage	POHSSC Type O	OWORS Barrier	POHSSC Type F	OWOCRS [2]	POHSSC Type F [2]
Philadelphia PA	L	6	13.7	33.2	8.8	19.0	8.8
Philadelphia PA	W	0	68.5	1228.4	501.6	703.0	1003.2
New Orleans LA	L	6	27.4	398.4	149.6	228.0	290.4
New Orleans LA	W	0	41.4	630.8	228.8	361.0	466.4
New York NY	L	6	13.7	166.0	44.0	95.0	88.0
New York NY	W	6	27.4	863.2	246.4	494.0	484.0
San Francisco CA	W	6	54.8	365.2	149.6	209.0	299.2
Galveston TX	W	6	41.4	199.2	132.0	114.0	264.0
Los Angeles CA	L	6	13.7	66.4	52.8	38.0	96.8
Los Angeles CA	W	0	41.4	199.2	176.0	114.0	352.0
Pascagoula MS	W	6	54.8	199.2	123.2	114.0	246.4
Sabine TX	L	6	13.7	66.4	26.4	38.0	44.0
Sabine TX	W	6	27.4	298.8	105.6	171.0	211.2
Port Aransas TX	W	6	27.4	199.2	88.0	114.0	158.4
Boston NA	L	6	68.5	697.2	290.4	399.0	580.8
Portsmouth VA	L	6	13.7	66.4	35.2	38.0	61.6
Portsmouth VA	W	6	13.7	33.2	17.6	19.0	44.0
Seattle WA	L	6	27.4	99.6	44.0	57.0	79.2
Clearwater FL	L	6	27.4	265.8	96.8	152.0	176.0
Chicago IL	L	6	27.4	66.4	26.4	38.0	44.0
		102	643.9	6142.0	2543.2	3515.0	4998.0

(1) See Note (1), Table 10-7

(2) See Note (2), Table 10-7

with one C130 kept in reserve at each base, the following aircraft were assumed available:

Elizabeth City, N.C.... 3 HC130B
St. Petersburgh, FL.... 3 HC130B
San Francisco, CA...... 2 HC130H

The C141A are assumed to be made available by the USAF for use at any U.S. airport with 5000 ft. runways ready for loading and refueling as follows:

16 aircraft on the 6th hour after request,
1 aircraft per hour after the sixth hour,

with a maximum of 36 C141 aircraft total available for pollution response duty. It should be noted that while the C141 are available for emergency duty (i.e., to transport needed equipment to a spill) they are not usually available for non-emergency duty, e.g., to return the same equipment after the spill response is completed, or for practice drills.

10.2.2 Loading Assumptions

Because of the large quantities of equipment involved, only gross weights and volumes to be moved were considered. Detailed loading plans were not made up.

The C130B and C130H load-payload curves are given in Appendix F. For practical purposes, the following range/payload combinations were assumed:

AIRCRAFT	RANGE, n.mi.	PAYLOAD, lbs.	PAYLOAD, cu. ft.
C130B	1600	16,000	3600
	500	20,000	3600
C130H	1500	37,000	3600
	1000	40,000	3600
C141A	2000	70,000	5300
	3000	60,000	5300

Both volume and weight for these aircraft are limited in theory but in practice only the weight limit need be considered. This can be seen from the following comparison:

CARGO DENSITIES		MAX. PAYLOAD DENSITIES	
ADAPTS	30 lbs/cu.ft.	C130B	
		1600 n.mi.	4.4 lbs/cu. ft.
POHSSC		500	5.5
Type OW	18	C130H	
Type F	26	1500 n.mi.	10.3
OWORS	16	1000	11.1
OWOCRS	16	C141A	
		2000 n.mi.	13.2
		3000	11.3

The cargo densities should be reduced by about .8 to allow for packing density. This gives a minimum density of 12.8 lbs/cu.ft. for the OWORS, which is barely below the maximum achieveable aircraft load density. Hence in almost all cases air transport will be limited by weight rather than volume.

With this simplification, it is possible to determine the number of aircraft loads required to deliver each of the items required for a massive spill. This is done in Table 10-9a. This Table also includes truckloads required, based on a 40 ft. flat bed tractor and semi-trailer of 80,000 lbs. gross weight and 50,000 lbs. payload. The volume that can be carried is roughly 8 x 40 x 9 or 2880 cu. ft., which comes to about 17.4 lbs per cu. ft. Therefore, truck loads are limited by volume in the case of the OWORS, the OWOCRS and the Type OW barge. Otherwise they are limited by weight. For simplicity it will be assumed that all aircraft loads are weight-limited, and that enough tractor-trailers are available to transport equipment without limit on load or volume.

In order to determine offloading capability delivered to the debarkation point, it was assumed that the total offloading equipment delivered consists of 14% by weight of ADAPTS and 86% by weight of POHSSC type OW. These percentages correspond to the total weights shown in Table 10-8. The number of ADAPTS and POHSSC Type O delivered is then obtained by dividing the delivered weights by 6,000 lbs per ADAPTS and 13,700 lbs per POHSSC, and

TABLE 10-9 NUMBER OF EQUIPMENT LOADS REQUIRED FOR MASSIVE SPILL RESPONSE

	ADAPTS/	POHSSC Type O	OWORS -Barrier/	POHSSC Type F	OWOCRS	POHSSC Type F
C130B						
1600 n. mi.	4.5	46	112	94	63	169
500	3.6	37	90	75	50	135
C130H						
1500 n. mi.	1.9	20	49	40	27	73
1000	1.8	19	45	38	25	68
C141A						
2000 n.mi.	1.0	11	26	22	15	39
3000	1.2	12	30	25	17	45
Tractor and Semi-Trailer	1.4	17*	49*	30	26*	54

*Volume limited. Form factor of .8 assumed.

multiplying by 1000 gal/min for ADAPTS and 250,000 gal for POHSSC.

In order to determine the skimming capability delivered, the same procedure was followed. The percentage breakdown for off-loading is 71% OWORS/Barrier and 29% POHSSC Type F. The weights were taken as 33,200 lbs and 8,800 lbs respectively. The capabilities were taken as 300 gal/min and 40,000 gal.

10.2.3 Delivery Profiles

Strategy 1, All Land

The truck-loaded equipment responds according to the estimates made in Section 7, i.e., 105 minutes plus travel time at 33.33 knots. Water-based equipment must be retrieved from its vessel (whether on a launch ramp or in the water) and loaded on to semi-trailers. It is assumed that these will be commercially available tractor semi-trailers, leased or rented as required. The intervals for waterborne equipment delivery then are carried out in parallel with those for land delivery, and are as follows:

(a)	Alert time	15 min.
(b)	Assembly of personnel	45
(c)	Briefing	15
(d)	Equipment retrieval	60
(e)	Tractor Semitrailer availability and delivery; acquire loaders	120
(f)	Load	160
(g)	Road Time equals Response Range/33.33 knots	

Activities (d) and (e) are simultaneous and are sequential with the others. The net result is a response time of 255 minutes plus road time at 33.33 knots. Response time is calculated to the time of arrival of the trucks at the debarkation point, and does not include unloading or delivery to the spill. The response times to each of the three debarkation points are shown in Table 10-10. Since it is assumed that adequate land transport is available, the recovery capabilities listed in Table 10-7 will arrive at the three debarkation points without regard to weight or volume. The total offload capability at the debarkation point at anytime is taken to be the cumulative ADAPTS capability in

gallons/minute and the cumulative POHSSC Type O capability in gallons up to that time. The total skimming capability of the debarkation point is similarly determined from the cumulative OWORS/Barrier capability in gallons/minute and POHSSC type F capability in gallons. The cumulative offloading and skimming capabilities arriving at the three debarkation points is shown in Figures 10-10, a, b, and c.

Strategy 2, Land/Air/Land-Regional Collection

The regional airports chosen are listed in Table 10-11. If the massive spill is close enough to a particular site, land response is employed instead of air. This occurs for Seattle in Scenario A, and Philadelphia and New York in Scenario C.

In this strategy the truck time to the regional airport from the equipment site is calculated as for Strategy 1, where the airport takes the place of the debarkation point. The times are shown in Table 10-12. From airport to debarkation point, the times are shown in Table 10-12. From airport to debarkation point the time is the same as the response time for Option 4, Dual Mode Air/Land (see Section 7.4.4) except that instead of the intervals (a) Alert time (b) Assembly (c) Briefing, which together contribute 75 minutes, aircraft availability time is used. For the USCG aircraft at Elizabeth City, Clearwater, and San Francisco, the availability time is taken to be 1 hour, concurrent with land delivery to the airport. For USCG aircraft at other than USCG Air Bases, the availability time is taken to be 2 hours. For C141 aircraft the availability is as assumed previously: 16 aircraft at the 6th hour, and one per hour thereafter up to 36 aircraft. The distance from destination airport to debarkation point is assumed to be 50 n. miles, covered by tractor-semitrailer leased for the purpose. The unloading and loading times are as given in Section 7.4.4, based on the availability of commercial or DOD loading equipment. The times from the airports of Table 10-11 to the three debarkation points, under the above assumptions, are given in Table 10-13. When an aircraft has completed a delivery (i.e., when the time shown in Table 10-12 has elapsed) it is avail-

TABLE 10-10 RESPONSE TO MASSIVE SPILLS - STRATEGY NO. 1 (HOURS) (1)

		TIME TO PORT ANGELES	TIME TO KEY WEST	TIME TO ATLANTIC CITY
Philadelphia PA	L	66.0	31.3	3.2
Philadelphia PA	W	68.5	33.8	5.7
New Orleans LA	L	58.7	18.1	30.4
New Orleans LA	W	61.2	20.6	32.9
New York NY	L	66.7	33.1	4.2
New York NY	W	69.2	35.6	6.7
San Francisco CA	W	25.3	72.5	68.6
Galveston TX	W	57.0	27.7	35.9
Los Angeles CA	L	28.6	61.4	65.9
Los Angeles CA	W	31.1	63.9	68.4
Pascaqoula MS	W	63.7	17.7	24.4
Sabine TX	L	54.8	23.2	35.4
Sabine TX	W	57.2	25.7	37.9
Port Aransas TX	W	57.0	30.0	42.2
Boston MA	L	69.0	37.6	8.8
Portsmouth VA	L	67.5	25.5	7.0
Portsmouth VA	W	60.0	28.0	9.5
Seattle WA	L	3.4	73.8	66.1
Clearwater FL	L	70.0	8.0	25.8
Chicago IL	L	48.7	34.1	20.3

(1) Measured form time of receipt of OSC requests.

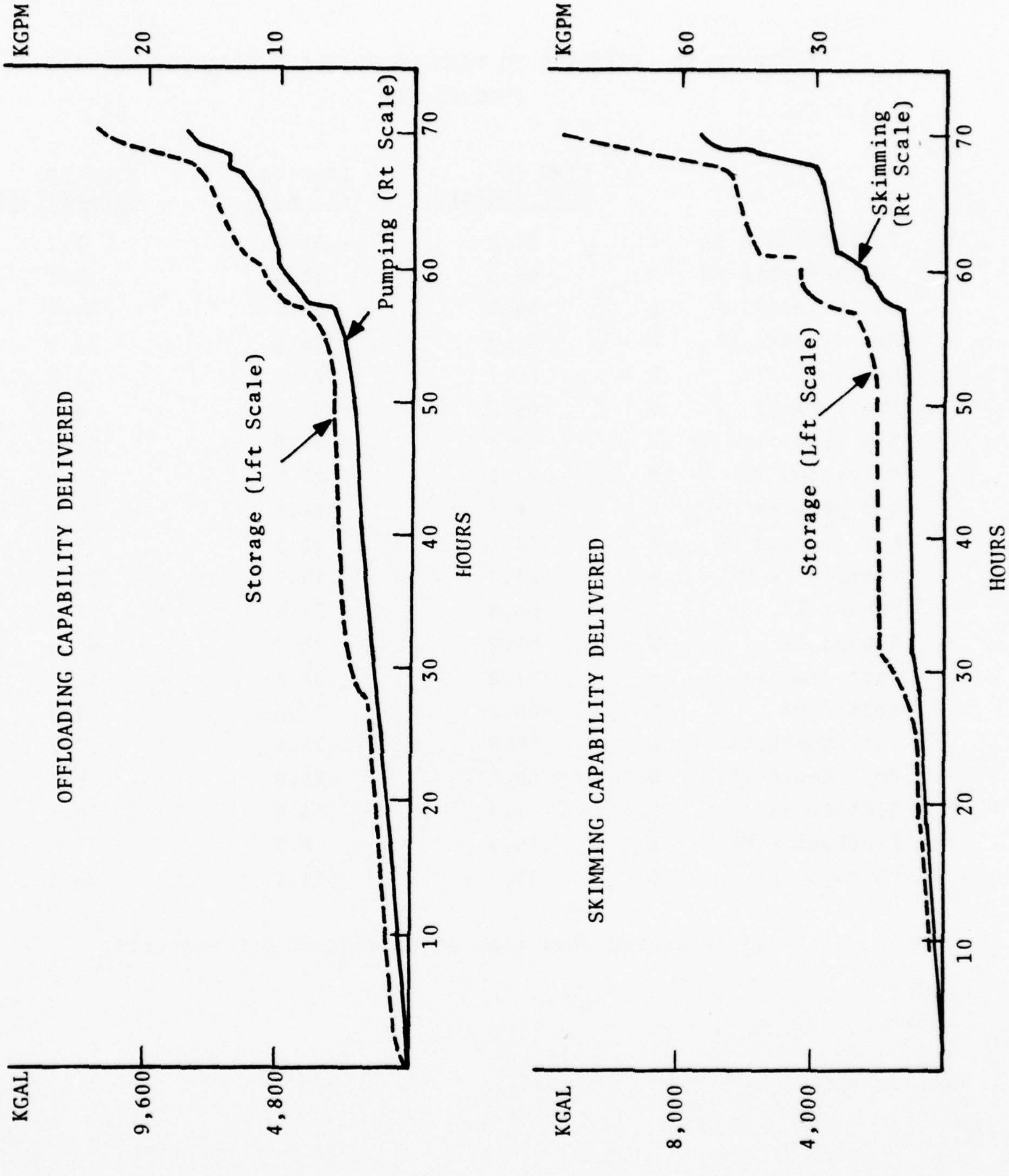

FIGURE 10-10a. STRATEGY 1, SCENARIO A

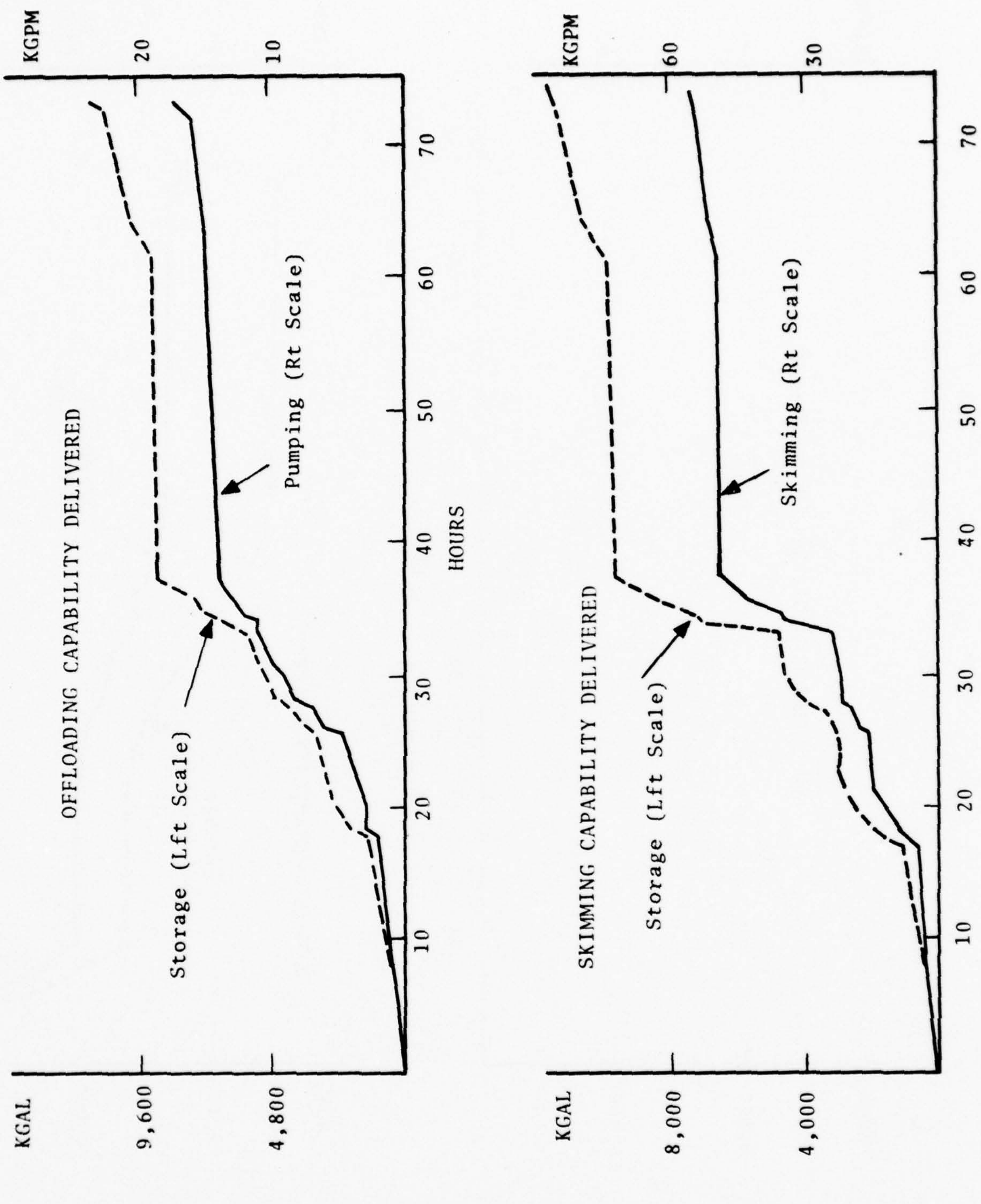

FIGURE 10-10b. STRATEGY 1, SCENARIO B

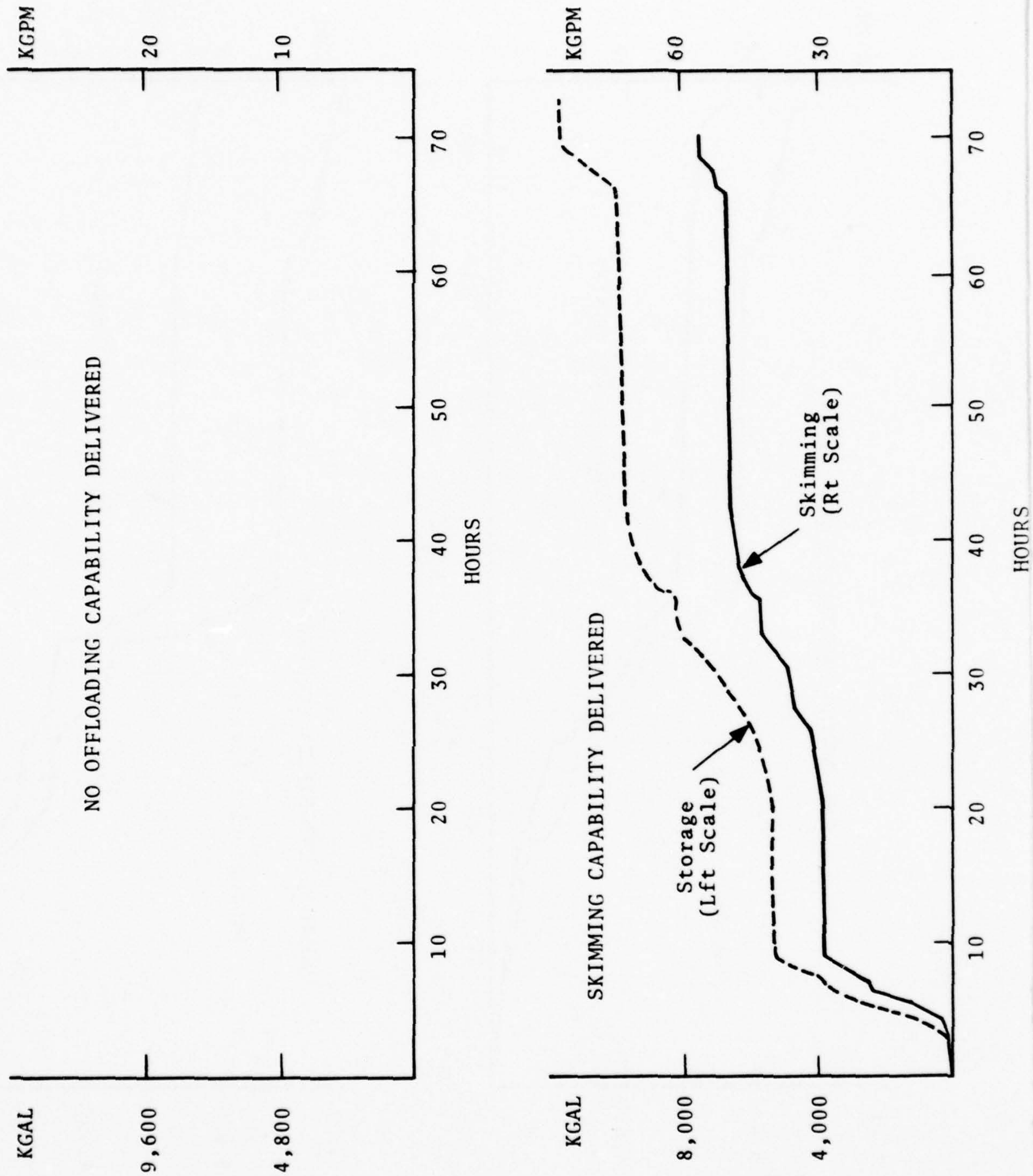

FIGURE 10-10c. STRATEGY 1, SCENARIO C

TABLE 10-11 AIRPORTS EMPLOYED FOR STRATEGIES 2 & 3

		AIRPORT FOR STRATEGY 2	AIRPORT FOR STRATEGY 3
Philadelphia PA	L	McGuire AFB	McGuire AFB
Phialdelphia PA	W	McGuire AFB	MCGuire AFB
New Orleans LA	L	Belle Chase CGAS	Belle Chasse CGAS
New Orleans LA	W	Belle Chase CGAS	Belle Chasse CGAS
New York NY	L	McGuire AFB	J F Kennedy (1)
New York NY	W	McGuire AFB	J F Kennedy (1)
San Francisco CA	W	San Francisco CGAS	San Francisco CGAS
Galveston TX	W	Belle Chasse CGAS	Ellington AFB
Los Angeles CA	L	Los Angeles CGAS (2)	Los Angeles CGAS (2)
Los Angeles CA	W	Los Angeles CGAS (2)	Los Angeles CGAS (2)
Pascaqoula MS	W	Belle Chasse CGAS	Belle Chasse CGAS
Sabine TX	L	Belle Chasse CGAS	Ellington AFB
Sabine TX	W	Belle Chasse CGAS	Ellington AFB
Port Aransas TX	W	Belle Chasse CGAS	Corpus Christi CGAS (3)
Boston MA	L	Otis AFB	Otis AFB
Portsmouth VA	L	Elizabeth City CGAS	Elizabeth City CGAS
Portsmouth VA	W	Elizabeth City CGAS	Elizabeth City CGAS
Seattle WA	L	Seattle CGAS (4)	Seattle CGAS (4)
Clearwater FL	L	Clearwater CGAS	Clearwater CGAS
Chicago IL	L	Clearview CGAS	Clearview CGAS (5)

(1) Alternate: McGuire AFB, Wrightstown, N.J.
(2) Alternate: March AFB, Riverside, CA
(3) Alternate: Kelley AFB, San Antonio TX
(4) Alternate: McChord AFB, Tacoma WA

TABLE 10-12 LAND DELIVERY TIMES FROM EQUIPMENT SITE TO AIRPORT (MINUTES)

EQUIPMENT SITE		STRATEGY # 2 AIRPORT	TIME	STRATEGY # 3 AIRPORT	TIME
Philadelphia PA	L	McGuire AFB	150	McGuire AFB	150
Philadelphia PA	W	McGuire AFB	300	McGuire AFB	300
New Orleans LA	L	Belle Chasse	110	Belle Chasse	110
New Orleans LA	W	Belle Chasse	260	Belle Chasse	260
New York NY	L	McGuire	180	New York (JFK)	180
New York NY	W	McGuire	330	New York (JFK)	285
San Francisco CA	W	San Francisco	270	San Francisco	270
Galveston TX	W	Belle Chasse	378	Ellington AFB	285
Los Angeles CA	L	Los Angeles	120	Los Angeles	120
Los Angeles CA	W	Los Angeles	270	Los Angeles	270
Pascagoula MS	W	Belle Chasse	435	Belle Chasse	435
Sabine TX	L	Belle Chasse	228	Ellington AFB	135
Sabine TX	W	Belle Chasse	378	Ellington AFB	285
Port Aransas TX	W	Belle Chasse	855	Corpus Christi	285
Boston MA	L	Otis AFB	192	Otis AFB	192
Portsmouth VA	W	Elizabeth City	162	Elizabeth City	162
Portsmouth VA	W	Elizabeth City	312	Elizabeth City	312
Seattle WA	L	Seattle	105	Seattle	105
Clearwater FL	L	Clearwater	105	Clearwater	105
Chicago IL	L	Glenview	133	Glenview	133

NOTE: Times are measured from receipt of OSC request.

TABLE 10-13 AIR/LAND TRANSPORT TIME FOR THREE MASSIVE SPILL SCENARIOS

(MINUTES)

FROM ORIGINATING AIRPORT	TO PORT ANGELES C130	PORT ANGELES C141	KEY WEST C130	KEY WEST C141	ATLANTIC CITY C130	ATLANTIC CITY C141
Belle Chasse	570	414	298	252	379	300
McGuire AFB	620	444	388	306	-	-
San Francisco	218	204	680	480	580	420
Elizabeth City	640	456	338	276	228	210
Clearwater	650	462	228	210	348	282
Los Angeles	368	284	590	426	620	444
Otis AFB	650	462	429	330	228	210
Seattle	-	-	670	474	620	444
Glenview IL	499	372	409	318	308	258
New York City	630	450	499	312	197	192
Ellington AFB	539	396	348	282	429	330
Corpus Christi	539	396	348	282	479	360

NOTES:

1. Transport time for C130 is 184 minutes plus air time from orginating airport to debarkation point at 295 n.miles per hour.
2. Transport time for C141 is 184 minutes plus air time from originating airport to debarkation point at 495 n.miles per hour.

able for another delivery at any of the airports employed in the strategy after a period of time equal to the delivery time from that airport. Thus, after a 570 minute delivery time form Belle Chasse to port Angeles the C130 involved will again be available at Belle Chasse after another 570 minutes, or at McGuire AFB after 620 minutes, or at San Franciso after 218 minutes, etc. Once reassigned to one or another airport the aircraft will not be available again until its next delivery is completed. Reassignment is made every 15 minutes for all airports, in order of proximity to the debarkation point; each airport is assigned the aircraft that has the most recent availability time at the airport. Upon reassignment the aircraft becomes unavailable for all airports for the period of time just described. The C130 aircraft are utilized in the same manner as the C141 aircraft, except for the longer flight times. Aircraft are assumed to be loaded to capacity or to the limit of equipment available at the originating airport at the time. Because of the above rules, departures at any airport are at least 15 minutes apart. They cease when all equipment delivered to the airport by land has been removed by air.

The cumulative offloading and skimming capabilities arriving at the three debarkation points is shown in Figures 10-11.a, b and c.

Strategy 3. Land/Air/Land - Local Collection

This stragegy makes use of local commercial or military fields in New York, Galveston and Corpus Christi area, rather than the regional airports. All other procedures are the same as for Strategy 2.

The cumulative offloading and skimming capabilities arriving at the three debarkation points is shown in Figures 10-12.a, b and c.

10.3 COMPARISON

The offloading and skimming requirements of the three Scenarios and the response capability that can be delivered by each strategy may now be compared. The requirements are summarized in

Figures 10-2 and 10-3 for offloading and 10-7, 10-8 and 10-9 for skimming.

Scenario A - PACIFIC PIGEON

Scenario A calls for 13,250 gallons/minute pumping capability from hour 6 through hour 54. This can not be achieved by strategy 1; strategy 2 meets the need at about hour 13, as does strategy 3. Similarly, while none of the strategies provide the 38 million gallons of storage called for, nevertheless, strategies 2 and 3 do provide between 8 and 10 million gallons of Type OW storage between the 10th and 20th hour, and over 12 million gallons by the 30th hour.

The skimming requirements for Scenario A are given in Figure 10-7. About 15 million gallons should be skimmed by the 100th hour, and about 22 million by the 200th hour. Strategy 1 provides about 10,000 gpm (600,000 gallons/hr) from hour 20 to hour 57, yielding about 22 million gallons up to that time. This is more than required at the 100th hour, but the buildup in the first 20 hours is somewhat less than required. It must be concluded, then, that strategy 1 would provide most but not all of the skimming requirement of Scenario A. Strategies 2 and 3 provide well over twice as much equipment as strategy 1 and hence would more than meet the skimming needs of PACIFIC PIGEON in terms of equipment delivery.

Scenario B - UNIVERSAL WONDER

Offloading requirements for UNIVERSAL WONDER are not as unambiguous as those for PACIFIC PIGION. As seen in Figure 10-3, they depend on the time spent offloading. Strategy 1 builds up to about 13,000 gallons/minute in 38 hours. If the pumps were all operating at the 38th hour, the cargo remaining would be offloaded in about 28 hours. When allowance is made for (1) use of the pumps arriving before the 38th hour, and (2) leakage during pumping, it appears that the leaking tanks would be emptied by about the 48th hour by strategy 1. The picture for strategies 2 and 3 is even more encouraging, since essentially 16-17,000 gallons per minute capability is delivered by the 20th hour (strategy 2) or 17th hour (strategy 3). It must be concluded,

then, that strategy 1 provides reasonably good response to the UNIVERSAL WONDER offloading requirement, and strategies 2 and 3 provide very good responses.

The skimming requirement for Scenario B is obtained from Figure 10-8. The amount of oil on the water increases from about 8 million gallons at hour 8 to about 15 million gallons at hour 125, remaining constant thereafter, in the absence of skimming. Strategy 1 provides about 10,000 gallons per minute of skimming capacity from the 20th to 34 hour, when the capability rises steeply to about 44,000 gallons per minute by hour 38. Thus, about 8.4 million gallons could be skimmed by hour 34; although strategy 1 provides the 8 million gallons recovery called for by the scenario, it does so at hour 34 instead of at the 8th hour. It is questionable whether adequate slick thickness would persist past the 34th hour.

The skimming capability delivered by strategies 2 and 3 is only slightly better than that provided by strategy 1 in the critical first 36 hours, and inferior to it in the time beyond the 36th hour.

<u>Scenario C</u> - Baltimore Canyon Trough OCS

The skimming requirements for this Scenario are shown in Figure 10-9. The total volume increases linearly to about 1.7 million gallons (after evaporation) at the 800th hour. All three strategies provide 1.8 million gallons per hour skimming capability in from 30 to 40 hours. Thus, all three strategies provide adequate skimming power; the major question is maneuvering and coordination.

As a variation on this scenario as presented, one may consider the effects of, say, tripling the outflow rate. In that case the spill would be similar to the Santa Barbara or Ekofiske blowouts. The amount of oil in the water (without skimming) would still increase linearly, reaching 5.1 million gallons in 800 hours, when it is assumed the wells are capped. Due to limited resources for sealing off uncontrolled OCS wells, however, it is likely that

a larger blowout would take longer to cut off. The rate of discharge, then, must be met for a longer period of time by the skimming equipment. The capability available, however, is over 800 times the requirement of the initially assumed discharge rate (1.8 million gal/hr vs 2,125 gal/hr) and hence is more than 250 times the trebled requirement.

Summary

The comparison of requirements and delivered capability presented above may be summarized qualitatively as follows:

Scenario[1]

Strategy	AO	AS	BO	BS	CO	CS
1	Poor	Marginal	Good	Marginal	-	Excellent
2	Marginal	Very Good	Excellent	Marginal	-	Excellent
3	Marginal	Very Good	Excellent	Marginal	-	Excellent

[1] First letter indicates Scenario, second letter indicates Offloading or Skimming. Thus, AO indicates Scenario A offloading.

It should be noted that the descriptors in the above table refer only to the ability of the three logistic strategies to deliver the required equipment. The effectiveness of the equipment in actually recovering the oil is much more difficult to assess, and the discussions given in the preceding subsections provide only an outline of some of the problems. The intent of those discussions, and of the present comparative assessment has been to determine whether the quantities and locations of response

equipment previously determined on the basis of non-massive spills are adequate to meet the demands of a massive spill. When the dynamics of the postulated spill scenarios and logistical strategies are considered (but not operational effectiveness), the qualitative outcomes are those shown in the preceding table.

While the delivery capabilities of Strategy 2 (or 3) range from marginal to excellent, it is seen from Section lo.1.3 that the total quantities of equipment available in Configuration 5 are generally substantially in excess of what is called for in any of the three massive spill scenarios. It is the purpose of the next section, therefore, to reconcile this difference and to determine efficient deployment levels that meet both massive and non-massive spill requirements.

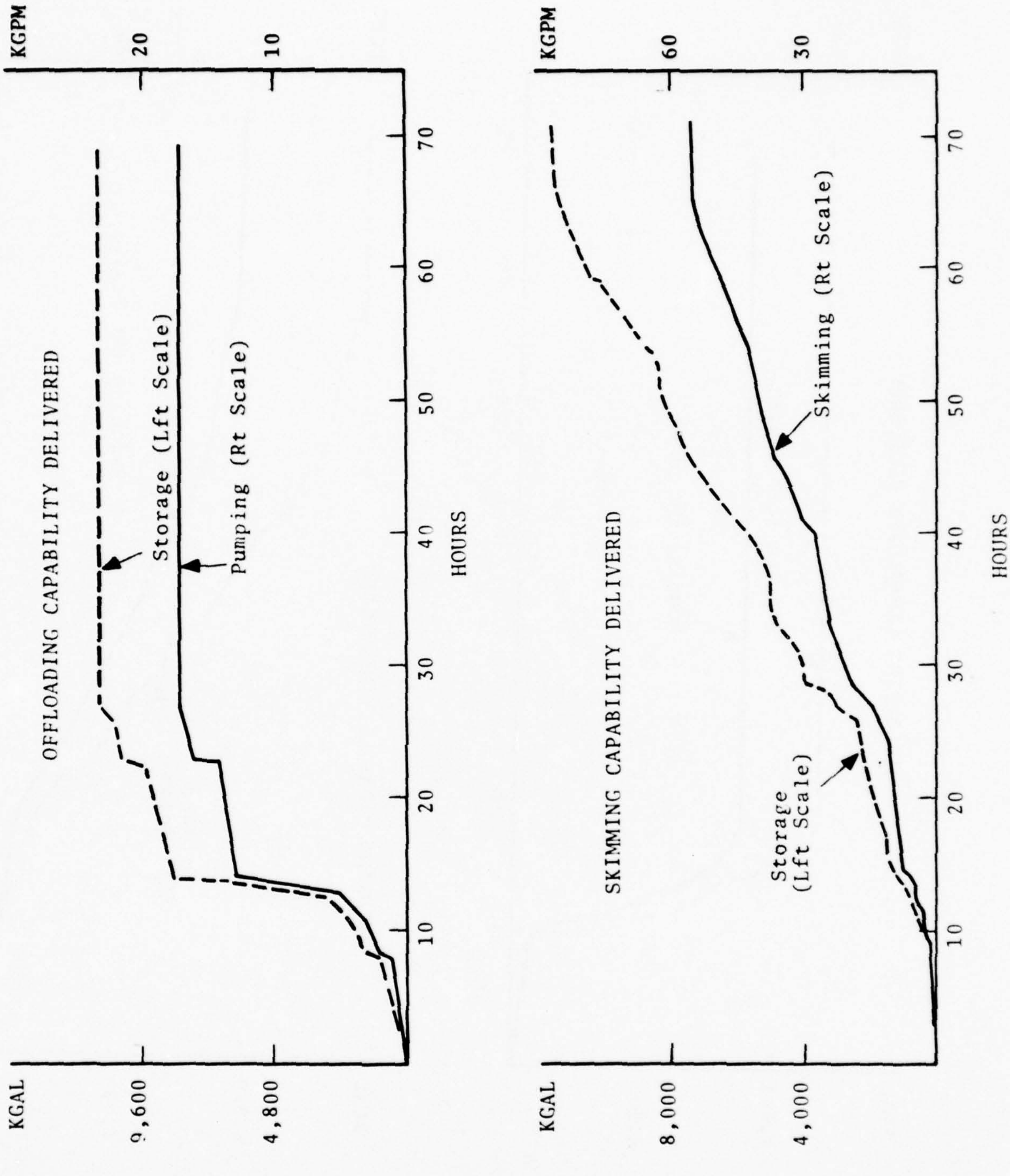

FIGURE 10-11a: STRATEGY 2, SCENARIO A

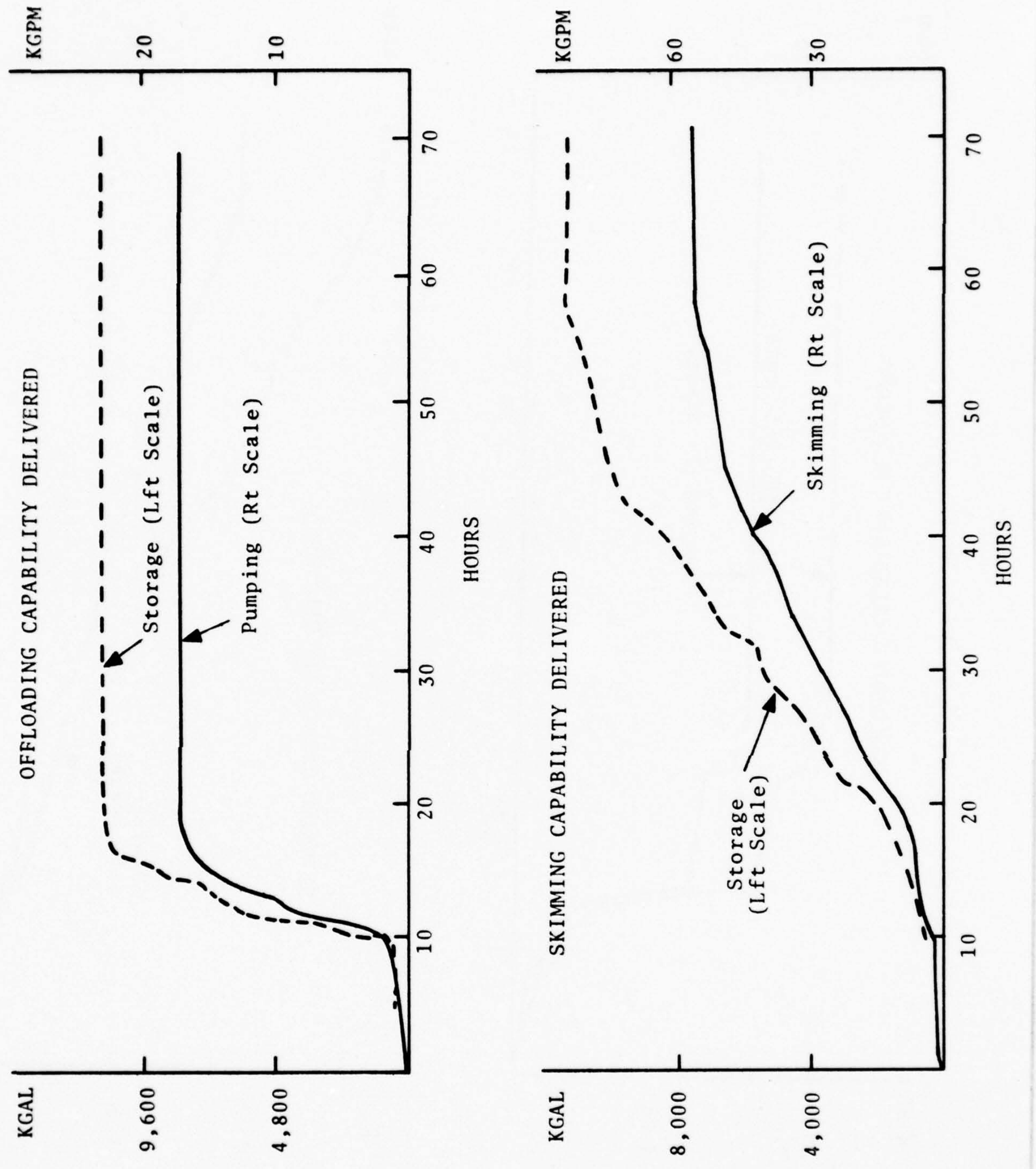

FIGURE 10-11b: STRATEGY 2, SCENARIO B

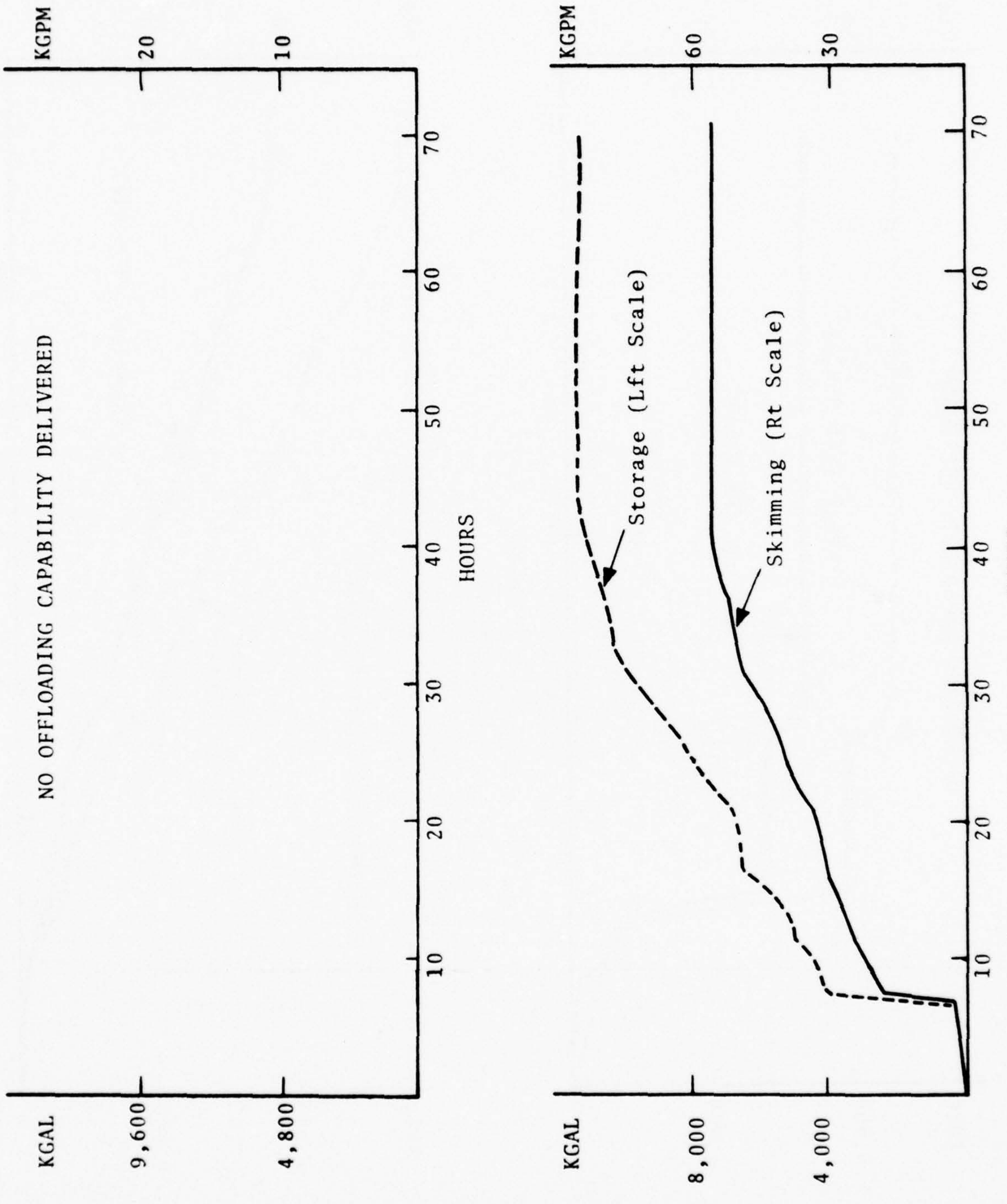

FIGURE 10-11c. STRATEGY 2, SCENARIO C

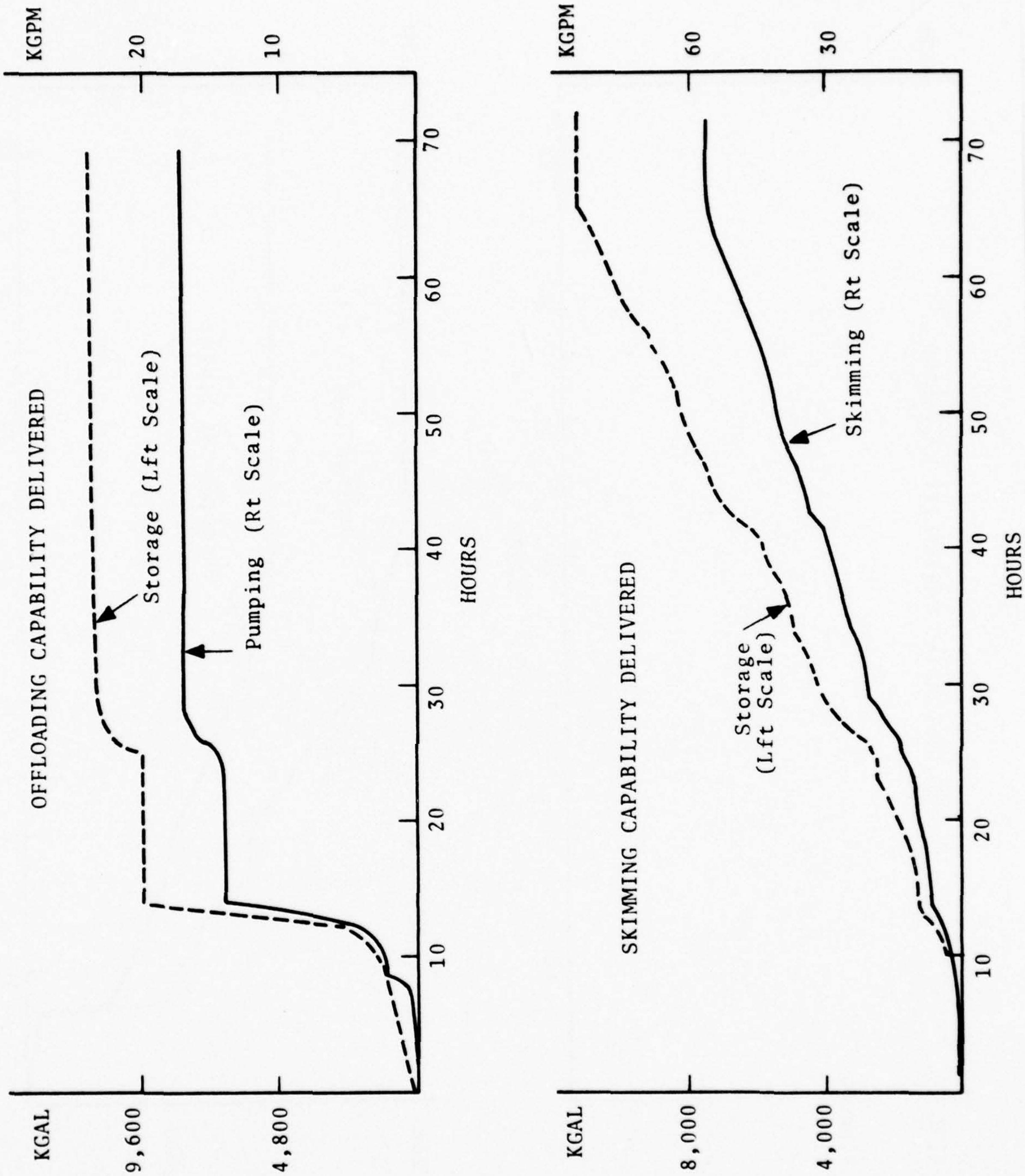

FIGURE 10-12a. STRATEGY 3, SCENARIO A

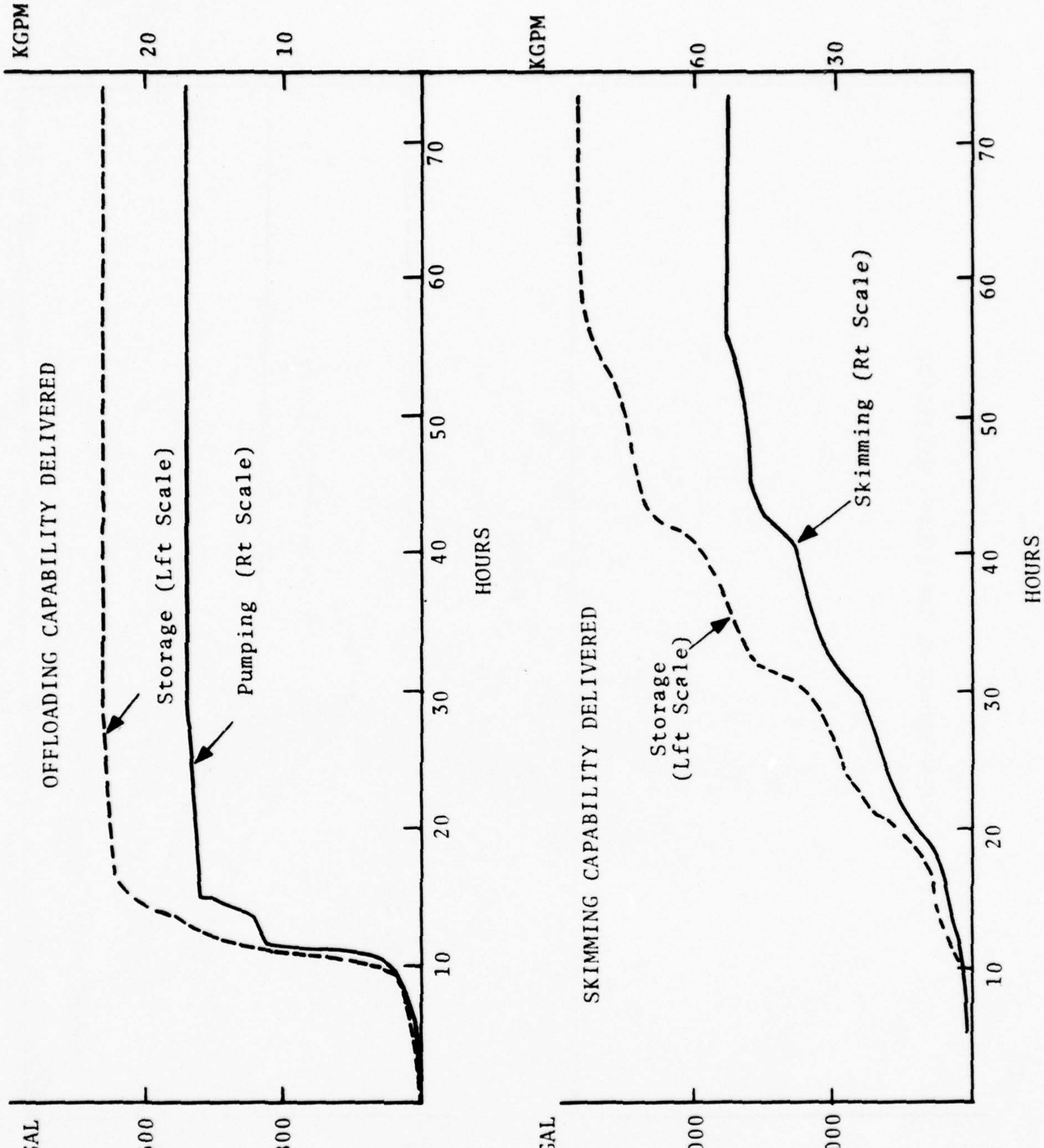

FIGURE 10-12b: STRATEGY 3, SCENARIO B

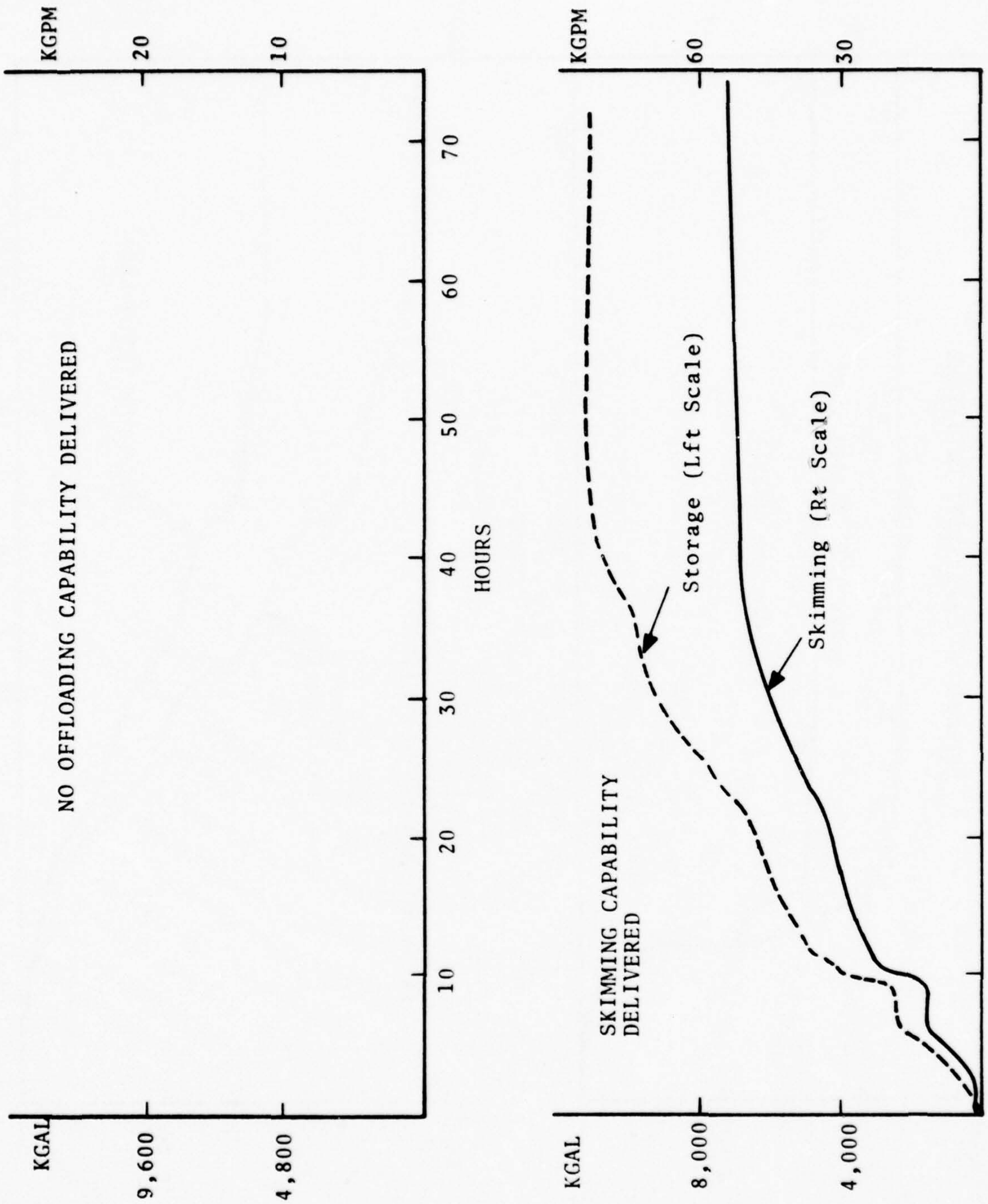

FIGURE 10-12c. STRATEGY 3, SCENARIO C

REFERENCES FOR SECTION 10

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10-2. Stolzenback, K.D., et al.: A Review and Evaluation of Basic Techniques for Predicting the Behavior of Surface Oil Slicks," Report No. MITSG 77-8, MIT Sea Grant Program, Massachusetts Institute of Technology, Cambridge MA 02139, March 1977.

10-2. Jeffrey, P.G., "Large-Scale Experiments on the Spreading of Oil at Sea and its Disappearance by Natural Factors," 1973 Proceedings of the Joint Conference on Prevention and Control of Oil Spills, Washington, D. C.

11. RECOMMENDED DEPLOYMENT

In sections 8 and 9 of this report locations and levels for USCG pollution response equipment were arrived at based on historical spill potentials throughout U.S. coastal waters. In section 10 three hypothetical massive spills were examined to determine what response to them would be afforded by the selected deployment of equipment. In doing this, it was found that the quantities of equipment provided in Configuration 5 generally exceeded that called for by any of the three massive spills. It will be seen in this Section, however, that the equipment levels of Configuration 5 are also substantially in excess of what would suffice if certain simplifications are made in the underlying assumptions. The most important of these simplifications will be explored in this section and a final system deployment will be arrived at. Specifically, the following possibilities will be examined:

1. Combining open water and harbor requirements.
2. Combining land-based and water-based capabilities.
3. Allowing for assistance from adjacent sites.

In addition, several system-wide considerations will be discussed relative to a final deployment. They are:

1. The role of air-delivered capability.
2. The effect on the deployment and recovery fraction of the maximum spill size allowed for.

When all these possibilities have been investigated, the information will be at hand to synthesize a configuration, with equipment capability levels, that will provide the most efficient match to the estimated spill threat, including that of a massive spill.

11.1 COMBINING OPEN WATER AND HARBOR REQUIREMENTS

The baseline unit requirements for harbor and for open water are given in Tables 9-11 and 9-12. These requirements were derived on the assumption that 40 million gallons of recovery capability would be allotted to cope with harbor spills and 30 million gallons to cope with open-water spills. If the same equipment can be employed for both types of spill, then it is not necessary to deploy 70 million gallons of recovery capability. Rather, it would be necessary to deploy only the larger of the two called for at each site. Since different amounts of non-USCG capability for harbor and open-water recovery were allowed for at each site, the required USCG capability at some sites is greater for open water than for harbor, despite the fact that the harbor spill potential is always greater than the open-water spill potential. Therefore each site must be examined to determine which is the larger requirement, as well as whether the two types of equipment are indeed interchangeable at the site.

Using the larger of the entries in Tables 9-11 and 9-12 we obtain the result shown in Table 11-1. Harbor requirements are noted by an asterisk, while the remaining entries are open-water requirements.

There are four sites at which harbor and open-water capability may not be interchangeable because of geographic constraints:

Philadelphia The open-water capability assigned to Philadelphia must serve all the Delaware Bay and the adjacent New Jersey - Delaware coast. The harbor capability, on the other hand, must cover Camden, Marcus Hook, and Newark, NJ. It may be advisable to locate the open-water capability in the lower part of Delaware Bay and to place the harbor capability at Glocester City. In this case, combining harbor and open-water capability would not be practical.

New Orleans The harbor capability at New Orleans must serve Baton Rouge as well as the Mississippi River to the Passes. The open-water requirement must serve the Gulf beyond the

TABLE 11-1. COMBINED HARBOR AND OPEN WATER REQUIREMENT FOR CONFIGURATION 5 (Thousands of Gallons)

SITE	TYPE	REQUIRED USCG CAPABILITY			
		PUMPS	STORAGE (1)	SKIMMING	CONTN'MNT
Philadelphia	L	210	*46/149	*398	210
Philadelphia	W	6480	1065/4610	*6722	6480
New Orleans	L	870	*267/618	*2246	870
New Orleans	W	2520	*632/1790	5304	2520
New York	L	390	65/267	*436	390
New York	W	3090	515/2193	*4044	3090
San Francisco	W	2160	360/1540	2160	2160
Galveston	W	1590	270/1130	*2160	*2000
Los Angeles	L	420	70/300	420	420
Los Angeles	W	2520	420/1790	2520	2520
Pascagoula	W	1410	*280/1000	2340	1410
Sabine	L	90	*50/120*	*400	90
Sabine	W	1380	225/986	1600	1380
Port Aransas	W	1240	170/750	1050	1050
Boston	L	3210	530/2280	3210	3210
Portsmouth	L	390	65/275	390	390
Portsmouth	W	390	65/275	390	390
Seattle	L	390	*70/280	390	390
Clearwater	L	840	*170/600	1220	840
Chicago	L	150	*40/110	*320	150
Barbers Pt	W	330	330/330	330	330
San Juan	W	150	150/150	150	150

(1) Offloading (Type OW)/Skimming (Type F)

* Harbor Requirement greater than Open Water Requirement

Passes. It is difficult for the same site to serve both functions effectively, so that combining the capabilities is not effective at New Orleans. Since the Pascagoula site can serve the Chandeleur, Mississippi and Breton Sound waters, the New Orleans open-water capability should be located on the southwest coast of the delta where it can serve the offshore drilling and LOOP activities.

Sabine, TX While Sabine is ideally situated for open-water response, it must also serve the Lake Charles harbor area via the Sabine and Calcasieu Rivers and the connecting intracoastal waterway, via land, or via the Gulf Coast and Lake Calcasieu. The response time by any of these routes may be excessively long compared to what may be achieved by locating the Sabine harbor capability farther inland, at, say, Orange or Lake Charles. The desirability of an inland harbor capability in this area must be determined by an examination of the response times from Sabine to the inland ports by truck and water.

Seattle In the Puget Sound area the distance from Seattle to Cape Flattery is substantial by land or by water. It may be desirable, when the Alaskan crude influx increases, to station the capability required for open-water at Bellingham and that required for harbor spills at Seattle.

The baseline USCG equipment complement of section 6 does not include different designs for harbor and open water recovery operations. To a great extent the baseline equipment is suitable for harbor as well as for the open water operation for which it is primarily intended. The major exception is the open water containment boom (OWOCS) which is bulkier and more expensive than required for most harbor containment purposes. Even in this case, however, one must weigh the advantages of a less expensive, more easily deployed harbor barrier against the elimination of duplicate equipment and the simpler training, logistics and maintenance required by a single type of equipment. One of the major advantages of using the OWOCRS equipment for harbor spills is the

increased operating experience afforded by harbor spills, which are more numerous than open water spills and more likely to occur in sea states that will allow deployment and retrieval of the OWOCRS.

Despite the geographic difficulties and the question of equipment suitability, the consolidation of open water and harbor capability seems advisable because it will reduce the required equipment investment by approximately 50% without substantially reducing the response capability. The major reductions in capability would occur in the four regions listed and would be in the form of extended response times, rather than reduced recovery capability. Since responses in these four bay regions are well within the six hour goal, the response time increase would affect only the mean response time and not the percent of responses greater than six hours. Although the change in mean response time has not been estimated, the distances suggest that it would be of the order of 0.5 hour for the ports involved, which may experience about 10 spills/yr. In this case the system-wide mean response time would increase by about 0.25 hr. This increase appears to be a reasonable price to pay for the large equipment saving involved.

The response time increase due to consolidating harbor and open-water capability is affected also by the land- and water-based trade-off. This will be discussed next.

11.2 COMBINING LAND- AND WATER-BASED CAPABILITIES

Six locations in Configuration 5 have separate land- and water-based equipment, as detailed in Table 11-2. The two sets of equipment, although located in the same general area, were treated as separate entities in determining the levels of Tables 11-1 and 11-2 and the recovery percentages of Figure 9-3. It was assumed that either the land-based or water-based equipment could respond to a spill, depending upon which was closer (in time). In effect, spills within 36 n.mi. of the port would be covered by water-based equipment, and spills beyond 36 n.mi. would be covered by the land-based equipment. (See Section 7.5).

TABLE 11-2. LAND AND WATER BASED CAPABILITY AT SIX LOCATIONS - CONFIGURATION 5.

		Spills Per Yr.	Response Time (hrs)	Capability Mill Gals
Philadelphia	L	0.30	4.4	0.40
Philadelphia	W	5.07	1.4	6.76
New York	L	0.40	4.8	0.44
New York	W	1.79	1.3	4.08
Portsmouth	L	0.43	7.1	0.48
Portsmouth	W	0.41	1.9	0.44
New Orleans	L	1.08	3.6	2.32
New Orleans	W	2.71	1.3	5.48
Sabine	L	0.42	3.1	0.44
Sabine	W	0.88	1.7	1.76
Los Angeles	L	0.42	4.0	0.44
Los Angeles	W	1.19	1.4	2.44

The question arises: Can these two sets of equipment be combined into one that serves both types of spills? If this combination is effective, more recovery equipment can be brought to bear on both types of spill, or, conversely, the same recovery effectiveness can be achieved with less equipment. Since the method chosen to combine land- and water-based capabilities at the same location affects the response times, three possibilities have been considered:

(1) Water storage on a towable vessel. For land response, the vessel would be towed to shore, the equipment removed by crane, and placed on a trailer or truck. Time required: about 30 minutes.

(2) Land storage on semi-trailer or truck. For water response the trailer would be hauled to a dock or launch area and transfered to water by crane. Time required: about 30 minutes.

(3) Land storage on a launchable vessel. This is the Transfer Waterborne mode described in Section 7.4.1. The equipment would be preloaded on a towable sled, which is mounted on a launch vehicle that can travel over the road and launch the sled from a ramp. Time required: about 15 minutes.

In the first approach the 30 minutes would be added to the response times of Table 11-2 for spills served by transfer to land mode. Similarly, in the second approach, the time would be added to the response time for spills serviced by water. In the third approach the 15 minutes would be lost in launching for spills serviced by water. However, this same amount of time would be saved for land-serviced spills upon arrival at the debartation point. A most important advantage of the third method, notably, is that it does not require a lift or crane. Lack of a lift or crane, or of an operator, could substantially increase response times for the first two methods. From the point of view of response times, then, the third method is clearly preferred.

Another consideration is the availability of land or water storage space. The allocations of Configuration 5 (Table 11-2) call for a preponderance of water-based equipment at five of the six sites in question. (Philadelphia, New Orleans, New York, Los Angeles, Sabine) with about an equal land/water division for the sixth site (Portsmouth-Norfolk). In practice, however, it may prove difficult to provide water-based storage. Wherever this is the case, transfer water-borne storage is the preferred approach since storage on land entails a response time penalty for a majority of the spills served by all ports except Portsmouth - Norfolk.

Effect on Equipment Levels and Recovery Percentage

When land- and water-based capabilities at the six sites in question are combined, different equipment levels from those shown in Tables 9-1 and 9-2 result from the allocation model of Appendix K. The 22 sites of Configuration 5 are reduced to the 16 sites of a new configuration, designated 5W. The levels are shown in Table 11-3. This table is for open water spill response only, since it was found in the previous subsection that the USCG harbor requirements are almost all less than the open water requirements, because of the non-USCG equipment available for harbors. A comparison of Configuration 5 with 5W shows that the percentage levels allocated to the combined water and land sites in Table 11-3 are not very different from the sum of the corresponding land- and water-based allocations of Table 9-1.

In addition to the percentage of allocations, the recovery fraction as a function of total U.S. capability also changes when land- and water-based sites are combined. The effect is shown in Figure 11-1 for open water spills, assuming optimum equipment allocation. It can be seen that for a given total capability the recovery for the combined configuration exceeds that for the separate configuration by 2% to 5%. Although this effect appears small, it takes on greater significance when viewed as a reduction in the capability required to achieve a given recovery percentage.

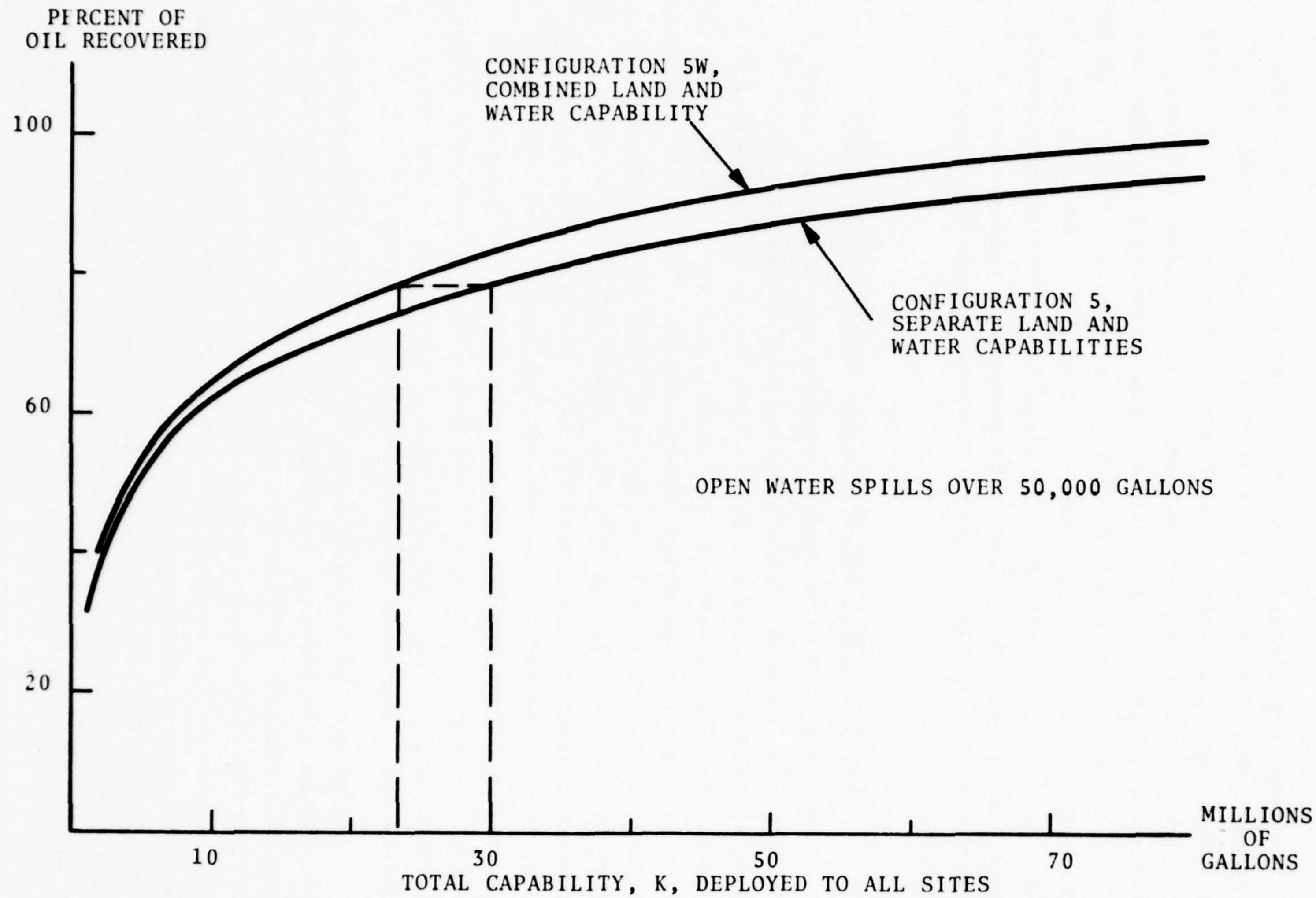

FIGURE 11-1. EFFECT OF COMBINING LAND- AND WATER-BASED CAPABILITIES

TABLE 11-3. RELATIVE EQUIPMENT LEVELS, PERCENT - OPEN WATER CAPABILITY, CONFIGURATION 5W

SITE	TYPE	TOTAL US CAPABILITY, MILLIONS OF GALLONS				
		2	6	10	20	30
Philadelphia	LW	20.9	35.3	36.7	28.0	21.1
New Orleans	LW	13.0	7.5	9.9	12.9	13.5
New York	LW	11.7	7.3	8.4	12.2	12.5
San Francisco	W	6.3	5.9	4.3	4.7	6.8
Galveston	W	5.3	5.3	3.9	3.5	5.0
Los Angeles	LW	9.9	6.8	7.2	10.9	10.6
Pascagoula	W	5.1	5.1	3.9	3.2	4.4
Sabine	LW	5.3	5.3	3.9	3.5	4.9
Port Aransas	W	4.7	4.7	3.7	2.7	3.1
Boston	L	9.5	6.7	6.9	10.4	10.1
Portsmouth	LW	4.0	3.2	3.3	2.1	2.0
Seattle	L	0.0	1.7	1.6	1.6	1.3
Clearwater	L	4.4	4.0	3.6	2.2	2.6
Chicago	L	0.0	0.0	0.8	0.5	.5
Barbers Pt	W	0.0	1.4	1.2	1.1	1.1
San Juan	W	0.0	0.0	0.8	.5	.5

The (nominal) 80% recovery percentage provided by 30 million gallons of open water capability in Configuration 5 can be attained with about 23.5 million gallons total capability in Configuration 5W. This 22% reduction in required equipment is a direct result of the fact that the equipment at the combined site serves more spills than the equipment at either one of the separate sites. In fact, any reduction in the number of sites would produce similar results, since the allocation model does not account for the increased average response time that results from fewer sites.

11.3 ASSISTANCE FROM ADJACENT SITES

When the equipment based at one site can be transported to service a spill in another region, an increase in capability results for the assisted site even though the total amount of equipment is not increased. This effect is treated in the allocation model of Appendix K by the use of assistance coefficients, a_{ij}, defined as the fraction of capability of site j that is added to the capability of site i. Although reasonable results (some of which will be described) can be obtained by the use of these coefficients, it should be emphasized that the technique is artificial. It substitutes an increase in response time for a reduction in capability level. In other words, the capability available from the assisting site is multiplied by a fraction a_{ij} to account for its later arrival. If the assisting site is close enough to the receiving site so that the regions of 6-hour coverage substantially overlap, a coefficient close to unity is not unrealistic. On the other hand, if the two regions are very far apart, a small assistance coefficient would account for the fact that the equipment arrives toward the end of the recovery operation and hence recovers less oil.

The assumptions of Section 9 placed the nominal recovery period from the 8th hour to the 96th hour for harbor operations and from the 10th to the 72nd hour for open water skimming. Equipment arriving at the debarkation point within the first six hours is assumed to be 100% effective; likewise, equipment arriving at the 96th (or 72nd) hour is of no practical use and will recover

no oil, so that an assistance coefficient of zero is justified. If the equipment arrives at an intermediate time the assistance coefficient can be set between 0.0 and 1.0, in proportion to the fraction of the recovery period remaining.

The above rationale for setting the assistance coefficients is an attempt to represent the reduced effectiveness of equipment arriving later than six hours. If the six-hour response time is an end in itself, a different approach must be used. One possibility is to assign a value close to unity if the storage sites are within the six-hour response time, and zero otherwise.

In either of these two approaches, sites within the six-hour zone may be thought of as a single site. [Note that for simplicity response time is calculated from site to site, rather than from site to spill.] Any equipment assigned to one site is largely available at the other, and vice-versa. If the mutual assistance coefficients are set identically to 1.0 for the two sites, then there are an infinite number of capability allocations to the two sites that result in the same recovery level. Hence, the optimum produced by the allocation program will not be unique.

Before discussing the results obtained with non-zero assistance coefficients, the values assigned to them for each of the two approaches will be presented below.

11.3.1 Local Assistance

In this approach, adjacent sites within 6 hours response time are assigned coefficients of 1.0. Adjacent sites between 6 and 10 hours away are assigned coefficients between .90 and .99, depending on the distance between the sites. Beyond 10 truck hours the coefficients are assigned the value, zero, which leaves Clearwater, Seattle, Barber's Point, Chicago and San Juan unassisted. The coefficients assigned by this scheme are given in Table 11-4 for Configuration 5W.

TABLE 11-4. LOCAL ASSISTANCE COEFFICIENTS FOR CONFIGURATION 5W

SPILL SITE	ASSISTING SITE/ASSISTANCE COEFFICIENT
Boston	New York/0.99
New York	Philadelphia/1.00, Boston/0.99
Philadelphia	New York/1.00, Portsmouth-Norfolk/0.98
Portsmouth/Norfolk	Philadelphia/0.98
Clearwater	None
Pascagoula	New Orleans/1.00
New Orleans	Pascagoula/1.00, Sabine/0.98
Sabine	New Orleans/0.98, Galveston/1.00
Galveston	Sabine/1.00, Port Aransas/1.00
Port Aransas	Galveston/1.00
Los Angeles	San Francisco/0.93
San Francisco	Los Angeles/0.93
Seattle	None
Chicago	None
Barbers Point	None
San Juan	None

11.3.2 Coastal Assistance

For this method, the coefficients for Configuration 5W were calculated by the following rules:

(1) Sites greater than 747 n. miles apart (about 860 statute miles) were assigned 0.0 assistance coefficients. This effectively isolated the sites to the three coastal areas: Atlantic, Gulf and Pacific.

(2) Sites less than 6 hours apart were assigned coefficients of 1.0

(3) Sites separated by more than 6 hours, but less than 78 hours were assigned assistance coefficients a_{ij} calculated as:

$$a_{ij} = 1.0 - (t_{ij}-6)/(78-6)$$

where t_{ij} is the response time in hours from site j to site i.

(4) Sites separated by more than 78 hours response time were assigned 0.0 assistance coefficients.

The results of applying these rules are shown in Table 11-5. The East Coast group includes New York, Philadelphia, Portsmouth/Norfolk, Boston, and Chicago, except that Chicago and Boston do not exchange assistance. The Gulf Coast group includes Clearwater, Pascagoula, New Orleans, Sabine, Galveston and Port Aransas, except that assistance is not exchanged between Clearwater and Galveston or between Clearwater and Port Aransas. On the West Coast, San Francisco and Los Angeles form a pair, and Seattle and San Francisco form a pair, but Seattle and Los Angeles do not exchange assistance. Finally, the Hawaii and Puerto Rico sites do not interact with any other sites.

11.3.3 Results

The two sets of assistance coefficients were applied to Configuration 5W. In the case of sites mutually linked by assistance coefficients of unity, the relative allotment of capability

TABLE 11-5. COASTAL ASSISTANCE COEFFICIENTS FOR CONFIGURATION 5W

SPILL SITE		ASSISTING SITE/ASSISTANCE COEFFICIENTS
BO	Boston	PH/0.94, NY/0.98, PN/0.85
NY	New York	PH/1.00, BO/0.98, PN/0.93, CH/0.75
PH	Philadelphia	NY/1.00, BO/0.94, PN/0.96, CH/0.77
PN	Portsmouth/Norfolk	PH/0.96, NY/0.93, BO/0.85, CH/0.76
CH	Chicago	PH/0.77, NY/0.75, PN/0.76
CL	Clearwater	NO/0.85, PG/0.89, SA/0.75
PG	Pascagoula	NO/1.00, GA/0.87, SA/0.91, PA/0.81, CL/0.89
NO	New Orleans	PG/1.00, GA/0.92, SA/0.96, PA/0.86, CL/0.85
SA	Sabine	NO/0.96, GA/1.00, PG/0.91, PA/0.96, CL/0.75
GA	Galveston	NO/0.92, SA/1.00, PG/0.87, PA/1.00
PA	Port Aransas	NO/0.86, GA/1.00, PG/0.81, SA/0.96
LA	Los Angeles	SF/0.88
SF	San Francisco	LA/0.88, SE/0.77
SE	Seattle	SF/0.77
BP	Barbers Point	
SJ	San Juan	

between the two sites is arbitrary, so only the total of the two allotments is meaningful. The percent recovery as a function of the total capability, K, is shown in Figure 11-2 for Configuration 5W. The three curves show recovery percentages for (a) no assistance, (b) local assistance, and (c) coastal assistance. The vertical dashed lines indicate the total capabilities that correspond to an 80% recovery level, which is achieved in Configuration 5 by a 30 million gallon open-water capability. For Configuration 5W, the following requirements can be read from the graph:

(a) No assistance - 23.5 million gallons

(b) Local assistance - 10.0 million gallons

(c) Coastal assistance - 8.0 million gallons

The relative equipment levels for these three cases are shown in Table 11-6. The brackets serve to group those sites with mutual assistance coefficients of 1.0. It can be seen that, in case (b), New York and Philadelphia together command 51.4% of the total capability, which in theory can be located at either site. Boston and Portsmouth/Norfolk, however, are assigned no capability of their own, since they have access, respectively, to .99 and .98, of the New York/Philadelphia capability. The Pascagoula/New Orleans group was allotted about the same capability level (14%) as the Sabine/Galveston/Port Aransas group, and the San Francisco/Los Angeles group. It should be noted, however, that San Francisco and Los Angeles have been made into a group even though their assistance coefficients are .93 rather than 1.0.

In order to test the sensitivity of the allotment levels to the assignment of assistance coefficients, case (b) was run with the value 0.5 for all local assistance coefficients. The results are shown in Figure 11-3 and Table 11-7, along with the original case (b) results for comparison.

It is seen from the Table that changing the assistance coefficients to 0.5 does not materially change the levels except that about 6% of the national capability is shifted from the Texas Coast to the Louisiana Coast. The percentage allocations for the

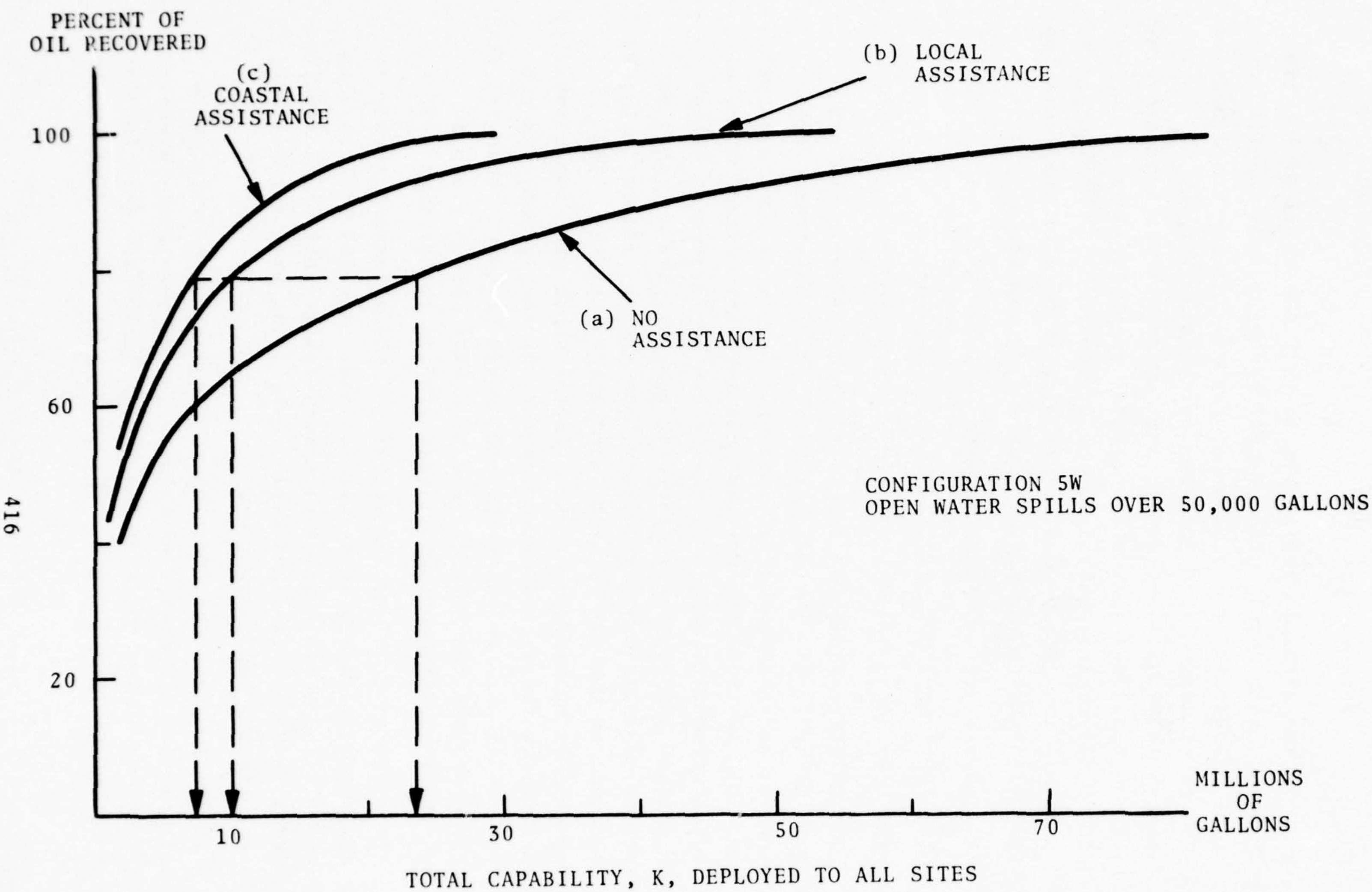

FIGURE 11-2. EFFECT OF SITE-TO-SITE ASSISTANCE

TABLE 11-6. RELATIVE EQUIPMENT LEVELS, PERCENT - OPEN WATER CAPABILITY, CONFIGURATION 5W

SITE	TYPE	CASE(a)	CASE(b)	CASE(c)
		TOTAL U.S. CAPABILITY* MILLIONS OF GALLONS		
		23.5	10.0	8.0
Boston	L	10.4	0.0	0.0
New York	LW	12.8	51.4	54.5
Philadelphia	LW	25.8		
Portsmouth/Norfolk	LW	1.9	0.0	0.0
Chicago	L	.5	.7	0.0
Clearwater	L	2.5	3.2	0.0
Pascagoula	W	3.4	13.9	27.8
New Orleans	LW	13.3		
Sabine	LW	3.8		
Galveston	W	3.7	14.7	6.3
Port Aransas	W	3.0		
Los Angeles	LW	9.5	13.3	10.5
San Francisco	W	6.1		
Seattle	L	1.5	1.3	0.0
Barbers Point	W	1.1	1.0	1.0
San Juan	W	0.5	.6	0.0

*Total of individual capabilities deployed to sites.

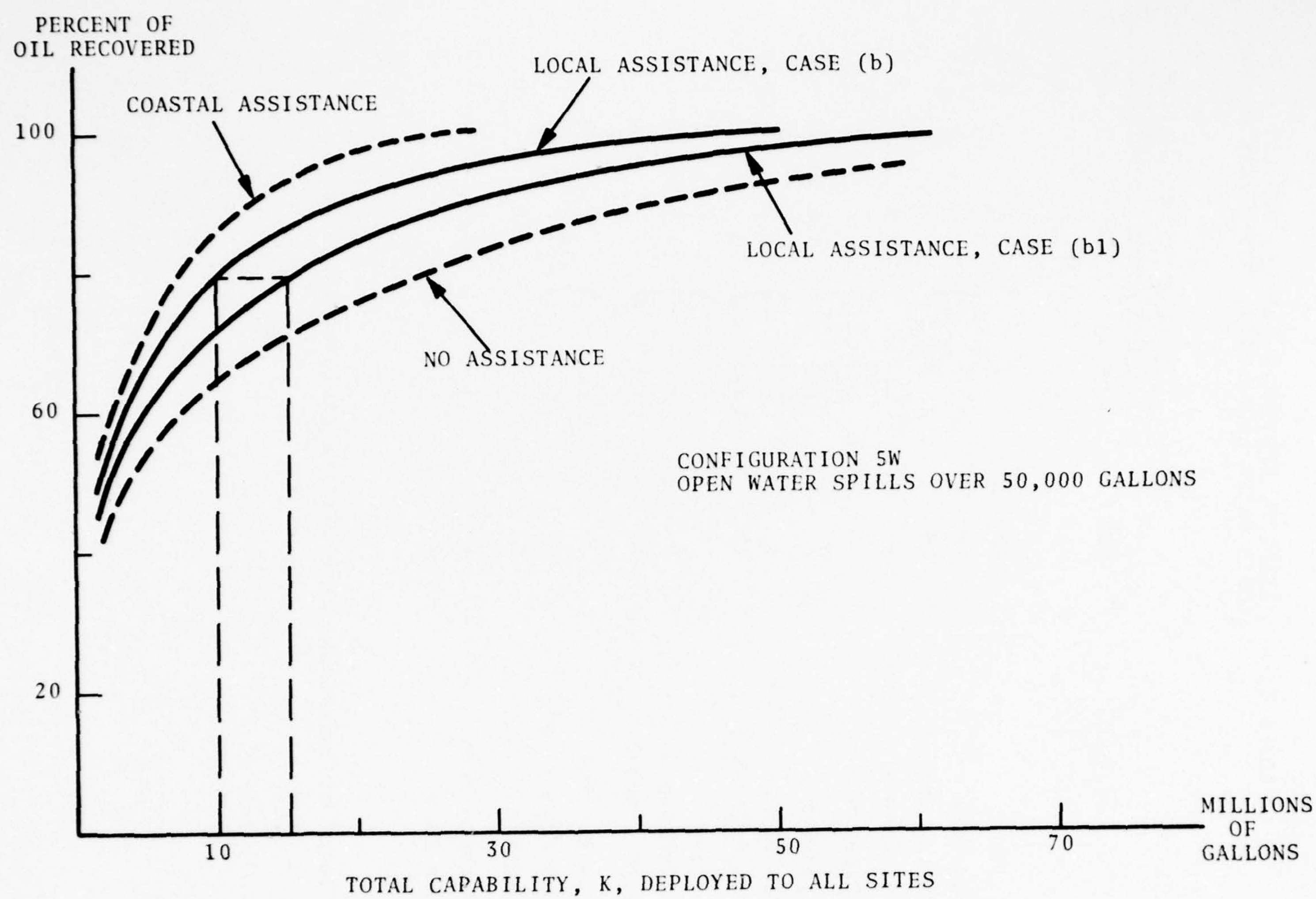

FIGURE 11-3. SENSITIVITY OF RECOVERY PERCENTAGE TO LOCAL ASSISTANCE COEFFICIENTS

TABLE 11-7. SENSITIVITY OF EQUIPMENT LEVELS, PERCENT,[1] TO LOCAL ASSISTANCE COEFFICIENTS

CASE	LOCAL ASSISTANCE COEFFICIENTS CASE(b)	CASE(b1)
a_{ij} range	0.9 to 1.0	0.5
Boston	0.0	0.0
New York, Philadelphia	51.4	49.0
Portsmouth/Norfolk	0.0	0.0
Chicago	0.7	0.6
Clearwater	3.2	2.6
Pascagoula, New Orleans	13.9	20.0
Sabine, Galveston, Port Aransas	14.7	8.8
Los Angeles, San Francisco	13.3	16.0
Seattle	1.3	1.4
Barbers Point	1.0	0.9
San Juan	0.6	0.6

[1]Calculated for Configuration 5W, Open Water capability, Total U.S. recovery capability of 10.0 million gallons in Case (b), and 15.0 million gallons in Case (b1).

East, West and Gulf Coasts are essentially unchanged. Once again, the Boston and Portsmouth/Norfolk spill threats are handled by assistance from New York and Philadelphia.

From Figure 11-3 one sees that the target 80% recovery is achieved in case (b1) by a total capability of about 15 million gallons, compared to 10 million gallons in case (b). Alternately, it can be seen that the recovery percentage drops from 80% to about 70% at a 10 million gallon total capability. These two cases may be taken to provide upper and lower bounds to the recovery achievable with local assistance. They suggest that a total capability of 15 million gallons will recover about 80% of the oil spilled (assuming it operates at full effectiveness when required) if at least one-half of the adjacent site capabilities can be brought to bear on the spill.

11.4 THE ROLE OF AIR DELIVERED CAPABILITY

Configuration 5W, which has been analyzed in the preceding sections, does not include an air-based site. Incorporation of air-delivered capability into the final configuration requires special discussion because response time and assistance coefficients do not completely characterize an air site as is the case for land- and water-based equipment. Air delivery is characterized, in addition, by:

(a) Volume and weight limitations on the initial response;

(b) Limits on the number of aircraft available and on their availability.

Failure to take account of these limitations was found to lead to highly unrealistic equipment levels at the air site, when non-zero values are used for the assistance coefficients from the air site to the other sites. The reason is that, even with an assistance coefficient of 0.5 from the air site to the East and Gulf coast sites, the optimum strategy is to concentrate a large capability at the air site, where its recovery effectiveness is amplified by 0.5 times the number of sites it can assist. If the

air site can assist, say, all 10 East and Gulf coastal sites then its effectiveness is about 4.5 times that of an equal amount of equipment elsewhere. The large amount of equipment called for at the air site was found to be far greater than the present or planned Coast Guard air lift capability.

For the above reason an air site must be assigned very low or zero assistance coefficients compared to other sites. The assistance coefficient from the air site to a collocated land site, however, may be assigned the value 1.0, as before.

When the Clearwater air site of Configuration 5a is appended to the combined land- and water-based sites of Configuration 5W, a new configuration (5Wa) results. With an assistance coefficient of 1.0 assigned between Clearwater land-based and Clearwater air-based sites, and zero coefficients to other sites from Clearwater by air, then the levels allocated and percent recovered are only slightly different from those obtained without the air site, as shown in Table 11-8, and Figure 11-4. The difference is due to those spills in the Great Lakes and Northern Maine that are serviced from the air site rather than from one of the land sites in the northeast. But servicing these spills from Clearwater produces a marked reduction in the percent of responses greater than six hours, as discussed in Section 8.4 and shown in Figure 8-14. Hence the addition of an air site should be viewed as a trade-off between the percentage of oil recovered and the percentage of responses within six hours. Figure 11-4 shows that adding one air site at Clearwater, FL causes a slight reduction of the recovery percentage for Configuration 5W, with local assistance. The reduction takes place because, for a fixed total capability, the addition of another site (of any type) reduces the capability available to all other sites, and the average effectiveness [oil recovered/recovery capability] is reduced. This is the same phenomenon as described in Section 11.3 with regard to combining land- and water-based sites. It appears that the small reductions in recovery percentage of Figure 11-3 can be sustained in order to obtain the substantial improvement in 6 hour response that are shown in Figure 8-14.

TABLE 11-8. EFFECT OF CLEARWATER AIR SITE ON CONFIGURATION 5W CAPABILITY LEVELS, PERCENT(1)

	CONFIGURATION 5W - NO AIR SITE		CONFIGURATION 5Wa - ONE AIR SITE	
	CASE(b)	CASE(b1)	CASE(b)	CASE(b1)
Boston	0.0	0.0	0.0	0.0
New York	51.4	49.3	51.2	48.8
Philadelphia				
Portsmouth/Norfolk	0.0	0.0	0.0	0.0
Chicago	0.7	0.6	0.0	0.5
Clearwater (land)	3.2	2.6	3.8	3.0
Clearwater (air)	-	-		
Pascagoula	13.9	20.8	14.4	20.9
New Orleans				
Sabine				
Galveston	14.7	8.8	14.7	9.0
Port Aransas				
Los Angeles	13.3	16.1	13.0	15.1
San Francisco				
Seattle	1.3	1.4	1.3	1.4
Barbers Point	1.0	0.9	1.0	0.9
San Juan	0.6	0.6	0.6	0.6

(1) Calculated for Open Water capability, Total U.S. recovery capability of 10 million gallons for case (b) and 15 million gallons for case (b1).

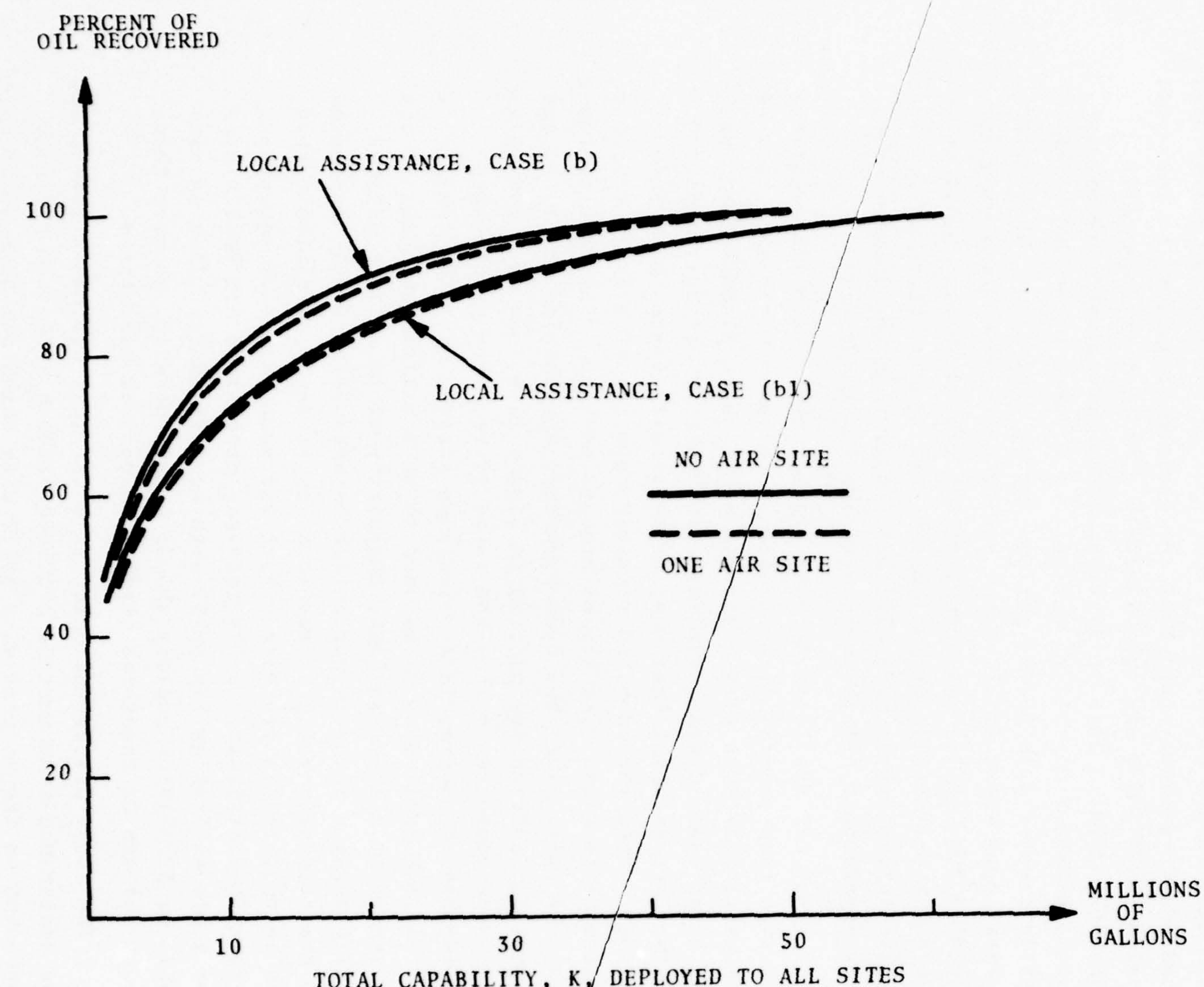

FIGURE 11-4. EFFECT OF THE ADDITION OF ONE AIR SITE TO CONFIGURATION 5W

11.5 EFFECT OF MAXIMUM SPILL SIZE

Examination of the MOSIS data base of historic spills greater than 50,000 gallons shows that the maximum spill for the four year period, 1974-1977, was approximately 8 million gallons (ARGO MERCHANT, 1976). This spill alone represents almost 1/4 of the total, of about 34 million gallons, of 67 open water and harbor spills greater than 50,000 gallons during that time. The second largest open water spill of the period released 840,000 gallons (GLOBTIK SUN, 1975). At the other extreme, a massive spill of 100,000 tons (30 million gallons) almost equals the total for the entire period and is several times larger than the largest spill ever experienced off the coasts of the United States.

Since oil spills in amounts greater than one million gallons are such rare events, it is difficult to justify the selection of any particular size as the maximum spill to be planned for. On the other hand, overall system performance is strongly affected by the largest spill that must be dealt with since the volume of oil may exceed the combined recovery capacity of all the response equipment that can usefully be brought to bear. For this reason a range of spill sizes has been examined, and results for 1, 8, and 30 million gallons are plotted in Figure 11-5. In each two curves have been computed to show the range of recovery percentages encompassed by appropriate assistance strategies. For example, if the maximum spill size is assumed to be 8 million gallons, it can be seen that a total response capability of 15 million gallons will provide a recovery percentage between 78% and 86%, depending on the effective value of the local assistance coefficients that can be realized in practice. With the same amount of equipment, optimally distributed, a 97% recovery percentage may be achieved for a one million gallon spill with no assistance. If a massive spill of 30 million gallons should occur, however, no more than about 56% can be recovered, even with coastal assistance.

The above discussion makes it clear that equipment levels and the assistance that must be provided between sites are strongly dependent on the largest size spill with which one must be prepared

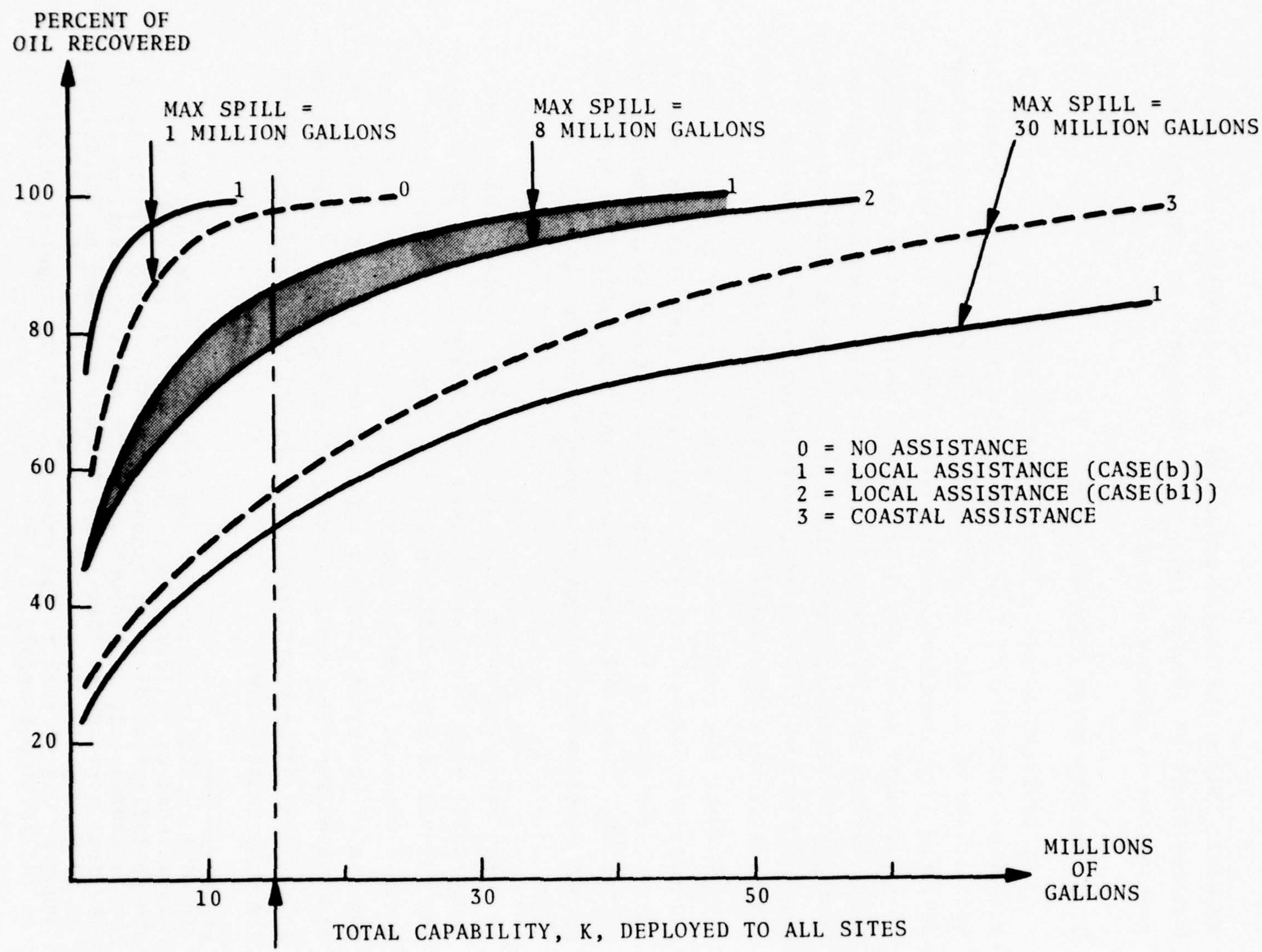

FIGURE 11-5. EFFECT ON RECOVERY PERCENTAGE OF MAXIMUM POSSIBLE SPILL SIZE

to deal. Since the stated objective is an effective response to a massive spill of 100,000 tons, it is necessary to consider this possibility in greater detail.

11.6 MASSIVE SPILL CONSIDERATIONS

In order to obtain a better assessment of the massive spill response capability of Configuration 5W, the total U.S. capability will be set at 15 million gallons and compared to the requirements obtained from the three massive spill scenarios in Section 10. This procedure is more realistic than simply setting the maximum spill size at 30 million gallons in the allocation model, as was done in the preceding subsection, for the reason that the scenarios take into account spill rates, evaporation rates, and other physical factors associated with massive spills.

To make the comparison it is first necessary to convert the percentage equipment levels of Table 11-7, case (b1), to absolute levels, and then to subtract the non-U.S. Coast Guard capabilities of Tables 9-7 and 9-8. The results shown in Table 11-9 are based on the same assumption that were used to derive Tables 9-9 and 9-10.

The first column of this table shows the total capability assumed for each site, as obtained from Table 11-7*. The remaining columns show the differences, for each site, between the assumed response capacity and the levels of non-U.S. Coast Guard open-water equipment that are expected to be available there, as determined from the smaller number of each pair in Tables 9-7 and 9-8. These differences constitute the deficit to be supplied by the U.S. Coast Guard.

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*The 49% capability shown for New York and Philadelphia was distributed as follows: 3% to Boston, 14% to New York, 29% to Philadlephia, 3% to Portsmouth/Norfolk. These distributions are approximately in proportion to the spill expectations of the four port areas. Similarly, 15% was assigned to New Orleans, 5% to Pascagoula, 3% to Sabine, 3% to Galveston, 2% to Port Aransas, and 8% each to San Francisco and Los Angeles, based on the spill potentials of Table 8-6.

TABLE 11-9. RECOVERY CAPABILITIES OF CONFIGURATION 5W
(Thousands of Gallons)

	TOTAL ASSUMED	REQUIRED USCG CAPABILITY PUMPING	STORAGE (1)	SKIMMING	CONT'MNT
Boston	450.	450.	74/320	450.	450.
New York	2100.	2100.	348/1492	2100.	2100.
Philadelphia	4350.	4350.	720/3090	4350.	4350
Portsmouth	450.	450.	74/320	450.	450
Chicago	90.	90.	15/64	90.	90.
Clearwater	390.	390.	65/277	390.	390.
Pascagoula	750.	750.	124/532	750.	750.
New Orleans	2250.	2250.	372/1600	2250.	2250.
Sabine	450.	450.	74/320.	450.	450.
Galveston	450.	450.	74/320	450.	450.
Port Aransas	450.	450.	74/320	450.	450.
Los Angeles	1200.	1200.	200/853	1200.	1200.
San Francisco	1200.	1200.	200/853	1200.	1200.
Seattle	210.	210.	35/149	210.	210.
	14790.*	14790.	2449/10,510	14790.	14790.

(*)15 million gallons, less requirements for Hawaii and Puerto Rico.

(1)Type OW/Type F. Skimming efficiency of 45% assumed for Type F Storage requirement.

Next, the required USCG capabilities of Table 11-9 are converted to units of equipment, based on Table 9-13: 4,950 x 10^3 gallons recovery per spill for ADAPTS, 233 x 10^3 gallons for the OWORS/Barrier and OWOCS/Skimmer, and POHSSC capacities of 250 x 10^3 gallons (Type OW) and 42,000 gallons (Type F). This conversion was done on a site-by-site basis, and the totals for all sites of Configuration 5W, except Hawaii and Puerto Rico, were calculated. These totals are compared with the requirements of the three massive spill scenarios in Table 11-10.

TABLE 11-10. BASELINE UNITS REQUIRED AND AVAILABLE IN CONFIGURATION 5W (ADJUSTED)

EQUIPMENT TYPE	AVAILABLE IN CONFIGURATION 5W	MAXIMUM CALLED FOR, SCENARIO X
ADAPTS	14	12 (Scenario A)
POHSSC, Type OW	18	97 (Scenario A)
OWORS/Barrier	68	54 (Scenario B)
OWOCS/Skimmer	68	54 (Scenario B)
POHSSC, Type F		
for OWORS	127	171 (Scenario B)
for OWOCS	254	308 (Scenario B)

ADAPTS It can be seen that the number of ADAPTS available in configuration 5W is surprisingly close to the maximum called for by the Scenarios. Since one pump was allocated to each site, it is also equal to the number of sites in Configuration 5W. This figure does not include spares. If each site were to maintain at least one spare, the number of ADAPTS available at any one time could be as many as 28, but more likely about 16-20 when allowance is made for repair and overhaul. We may conclude that Configuration 5W, with one ADAPTS plus one spare at each site, is adequate to supply the pumping capability called for by a massive spill.

POHSSC, Type OW

The number of Type OW flexible storage containers available in Configuration 5W is only about one fifth of that called for in Scenario A. That scenario called for 97 units to receive the oil from an average of 8.3 ADAPTS during the first 30 hours of off-loading preceding the arrival of large-scale hard-hull storage vessels. As pointed out in Section 10.1.1, the operational problems of feeding 8 Type OW barges simultaneously from a single vessel appear at present to be formidable, and the number of Type OW barges that could be used may well be limited by the number of barges that can be moored simultaneously, and the rate at which they can be exchanged. These operations, in turn, depend on the short-term availability of suitable work vessels. Until these and other problems can be resolved by testing and investigation, the usefulness of all 97 Type OW barges is questionable. The best conclusion that can be drawn at this stage is that the requirement is for a minimum of 18 Type OW barges (based on non-massive spill response) and a maximum of 97 Type OW barges (based on the 'worst case' Scenario). Before a firmer estimate can be developed more information is needed about (1) the practicality of exchanging Type OW barges in a confined area, possibly in heavy seas and in a minimum of time, (2) the availability of work vessels and crews capable of carrying out such an exchange operation, (3) the availability time of other (hard-hull) storage, (4) alternatives to offloading, such as refloating, burning, and sinking, and (5) the production capability of the manufacturer of the Type OW barges. Until such information is developed, a tentative number of 42 Type OW barges will be chosen, corresponding to the number called for in Configuration 5. This number may be considered the maximum required to cope with non-massive spills, i.e., with spills up to 8 million gallons.

OWORS/OWOCRS

The skimming units available in Configuration 5W exceed the requirements of Scenario B, whether the OWORS/Barrier or OWOCS/Skimmer is employed. While both have the same nominal recovery

rate (approximately 300 gallons/minute), they differ substantially in other characteristics. The OWOCRS has a much lower cost, more advanced testing status, and greater versatility and transportability. Its recovery efficiency, however, is about half that of the OWORS/Barrier, resulting in the need for twice as many of the POHSSC units.

<u>POHSSC, Type F</u>

The requirements of Scenario B exceed the number of these units that would be available in Configuration 5W by 20% in the case of the OWOCRS, and by 35% in the case of the OWORS/Barrier. These discrepancies are not considered large enough to warrant an increase in the Configuration 5W assignments, considering the uncertainties in the Scenario B recovery assumptions. It is concluded that 254 units called for in Configuration 5W are approximately adequate for most massive spills that can be envisioned.

11.7 RECOMMENDED DEPLOYMENT LEVELS

It is now possible to synthesize a deployment that will meet the minimum requirements of non-massive spills (i.e., spills under 8,000,000 gallons) and also provide a reasonably good match to the massive spills depicted in the three Scenarios of Section 10. The rationale is as follows:

1. With the possible exception of Philadelphia, New Orleans, Sabine, and Seattle, it is feasible to consolidate open-water and harbor response capabilities. This consolidation is recommended for the USCG baseline equipment in order to reduce the amount of specialized harbor equipment that might have to be purchased. If it is assumed, for example, that available CG open-water equipment would be deployed for harbor spills whenever necessary, then the total amount of equipment needed for Configuration 5 would be reduced by about 50% without substantial reduction in effectiveness.

The problem presented by the four sites listed above is the geographic separation between harbor and open-water spills. It

is advisable at these sites, either (1), to find an intermediate location for the equipment, accessible from both harbor and ocean, or (2), to improve the mobility of the equipment. The latter course is related to the question of land- and water-based sites.

2. Consolidating land- and water-based equipment at a location would increase the average response time from 15 to 30 minutes (6% to 12%) and reduce by about 22% the amount of equipment needed to achieve a given recovery percentage. This trade-off is considered desirable. It would become even more attractive if a transfer-waterborne mode (trailer-launcher) were developed, since this would reduce the penalty in response time, as well as alleviate the difficulties in combining open water with harbor capabilities by improving the mobility of the equipment. For example, land-mobile, launchable equipment pads would allow location of open water equipment in harbor areas without an excessive time penalty paid to trailer it to open-water debarkation points. It is estimated that consolidating land- and water-based capabilities will reduce the equipment needed to achieve 80% recovery from about a 30 million gallon national capability to about 22 million gallons.

3. The effect of site-to-site assistance depends on how much equipment is sent, how many assisting sites send it, and how far they are from the spill location. While adjacent sites, such as Philadelphia and New York, may in theory provide almost all of their equipment to the other within six hours, it would be excessively risky not to allow a substantial reduction in the available assistance percentage for such contingencies as:

a. Secondary spill coverage

b. Congested or blocked highways

c. Unscheduled equipment maintenance

d. Initial underestimation of the amount of oil spilled (or to be spilled)

e. Increased coordination time.

For these reasons equipment levels should not be based on large assistance coefficients; a value of .50 is recommended. When such coefficients are applied to local assistance, a reduction of total capability from the 22 million gallons discussed above to 15 million gallons results, while the same nominal 80% recovery percentage is retained. This is a reduction of about 32% in investment with no reduction in effectiveness, clearly a desirable effect.

4. There remains the question of massive spill response. At this point in the synthesis, a deployment of 15 million gallons total recovery capability seems to be adequate, provided the largest spill does not exceed 8 million gallons (26,000 tons). Not only is this level well below the Presidential goal of 100,000 tons, but it may well be below the actual spill levels observed in the next decade. A closer look at the massive spill capability of the proposed Configuration, however, shows that the numbers of baseline units it would provide in the contiguous United States meet the requirements developed in the three massive spill scenarios of section 10, with two exceptions:

(1) 18 Type OW POHSSC instead of 97 called for in Scenario A. In this case, however, the difficulties of successfully filling 97 flexible containers from a stranded vessel in a short period of time make it questionable whether all 97 containers could be used in one spill. On the other hand, 18 units can store only 4.5 million gallons, which is only adequate to unload vessels smaller than 15,000 tons under benign conditions. Accordingly, it is recommended that the number of POHSSC units stored in Configuration 5W be increased from 18 to an intermediate number such as 42 until more is learned about the operational problems of rapid offloading in heavy seas using these containers.

(2) 254 Type F POHSSC instead of 308 called for in Scenario B. This difference is not considered large enough to justify increasing the number recommended for Configuration 5W.

With the above adjustments and qualifications, the total U.S. equipment levels obtained for Configuration 5W provide a satisfactory match for a "massive" spill, as depicted in the three Scenarios. It would be misleading, however, to rely exclusively on these Scenarios to obtain an estimate of what may be needed to cope with a massive spill.

In gross terms the total U.S. recovery capability of Configuration 5W is only about 50,000 tons, compared to the recovery goal of 100,000 tons. The situation seems more favorable, however, when offloading and skimming are considered separately.

In the case of offloading, the major limitation of Configuration 5W levels is in storage containers. If, however, the number of Type OW POHSSC's deployed is increased from 18 to 42 then the true offloading capability is ADAPTS-limited to about 70,000,000 gallons or 230,000 tons, well over 100,000 tons. In the case of skimming, one must assume that a 100,000 ton petroleum cargo is very likely to be crude oil, which contains a large volatile fraction. For the international standard crude this fraction is about 1/2, leaving a skimming requirement of about 50,000 tons (at the worst). This is equal to the skimming capability of the Configuration 5W levels.

Hence, one may conclude that the 15 million gallon total U.S. recovery capability level, arrived at on the basis of non-massive spills and adjusted to include 42 Type OW POHSSC units, meets both the requirements for the three massive spill scenarios, and the gross estimated demands of a nominal 100,000 ton spill.

4. The final point to be considered is that of equipment transport for a massive spill. It has been assumed up to this point that almost all the equipment in the United States would be brought to bear on a massive spill. As seen in Section 10, this can not (and need not) be done in six hours. Neither can it be accomplished, in the case of spills on the Pacific Coast, without the aid of large numbers of DOD aircraft. The same is obviously

true for massive spills near Hawaii and Puerto Rico, although those two cases were not treated explicitly. In assessing the over-all requirements, then, the assumption of adequate air transport and logistic support must be examined. A complete assessment of massive spill logistics requirements, beyond that of Section 10, is clearly needed; the objective should be an operational logistics contingency plan for massive spills.

11.8 COSTS

Site Configuration and capability levels were developed above without direct regard for cost. It was assumed that total cost is proportional to total capability, which then was adjusted as far downward as practical without seriously affecting the recovery percentage or massive spill response. The proportionality between cost and capability is only approximate, but adequate for present planning purposes. The objective of this section of the report is to translate the recommended total U.S. capability levels into an approximate dollar figure in order to obtain an estimate of the cost of the resources required. To complete the picture, the staffing and maintenance requirements will be discussed briefly.

11.8.1 Baseline Equipment Purchase Costs

The total numbers of baseline units arrived at in Table 11-10 of the preceding section are tabulated in Table 11-11 along with the total purchase cost estimates (in 1976 dollars). These estimates were obtained from the per-unit costs given in Section 7.1. The number of POHSSC Type OW barges recommended for Configuration 5W has been increased from 18 to 42, as per the above discussion. The total weight and size are also tabulated for use in deriving vehicle costs. Finally, the number of units has been increased by about 10% to allow for maintenance.

As discussed previously, the OWORS/Barrier has a poor cost/performance ratio compared to the OWOCRS, and hence is not recommended for deployment, notwithstanding its need for

TABLE 11-11. APPROXIMATE PURCHASE COST, SIZE AND WEIGHT OF BASELINE SYSTEM UNITS

BASELINE UNIT	NUMBER REQUIRED	THOUSANDS OF POUNDS	CUBIC FEET	THOUSANDS OF 1976 DOLLARS
ADAPTS	16	96	320	960
POHSSC Type OW	46	630	33,948	11,040
OWORS/Barrier*	75	2490	155,250	67,800
OWOCRS	75	1425	82,500	13,125
POHSSC, Type F				
for OWORS*	140	1232	47,880	12,600
for OWOCRS	280	2464	95,760	25,200
TOTALS **	-	4615	212,528	50,325

* Not recommended for deployment. Included for comparison only.

** Exclusive of OWORS/Barrier and associated Type F POHSSC

fewer POHSSC Type F storage units.

It is interesting to note that the item with largest total size, weight and cost is the Type F POHSSC, because of the large quantity (280) required.

11.8.2 Vehicle Costs

The C130 and C141 aircraft costs are sustained for purposes other than pollution response at present. It will be assumed that such an arrangement will continue indefinitely. If an air site for pollution response is established at Clearwater (Configuration 5Wa) or at Elizabeth City (Configuration 5Wb), it is likely that the C130 aircraft stationed there will perform SAR missions primarily, and pollution response secondarily. Hence no additional costs would be incurred for the aircraft themselves.

Tractor-trailer purchase costs are close to one dollar per pound of capacity (See Section 7.2). From Table 11-11 it is seen that this amounts to about $4.6 million if the OWOCRS is employed, and if all equipment is stored on tractor trailers. At the other extreme, if all the equipment is stored on water, on say, the FSD, then vehicle purchase costs become much more difficult to estimate because of the uncertainty in FSD production cost. Although developmental models of the FSD are about $80,000, production models would probably be closer to $20,000 each. Using this figure and allowing 15,000 lb load per FSD gives a vehicle cost of $1.33 per lb., not very different from the tractor-trailer cost per pound. The total cost would be about $6.1 million.

In actuality, a mixture of tractor-trailer and FSD units may be employed if a transfer waterborne vehicle is not developed. The cost of the latter is difficult to estimate, but one may take the tractor-trailer cost as a minimum, and the sum of FSD and tractor-trailer per lb costs as an average. Thus a transfer waterborne vehicle might cost about $2.33 per lb of equipment or a total of about $10.7 million dollars. The greatest uncertainty in this estimate is the cost of the FSD production model employed, and the developmental costs.

The number of tractor-trailers is estimated as the total weight of equipment divided by 50,000 lb. The number of FSD or equivalent vehicles is estimated as the total equipment weight divided by 15,000 lbs. The results are 93 tractor/semi-trailer units of 80,000 gross weight, and 50,000 payload, or 307 FSD units of 15,000 lb payload. The number of trailer-launcher units required for transfer waterborne is probably closer to the number of FSD's required.

A final element of transport cost should be noted: it is to be expected that DOD will provide C141 aircraft for massive spill response on a reimbursable basis. If such is the case, funds must be set aside, probably in the revolving contingency fund, for transfer to DOD in the event of a massive spill.

11.8.3 Support Equipment

No attempt will be made to estimate support equipment amounts or costs, but the major items will be noted. Only support equipment devoted to pollution response will be considered.

Among the major items are:

a. Barrier retrieval system
b. ADAPTS maintenance shops
c. Barrier mooring equipment
d. Aircraft loaders for C130
e. FSD launch and retrieval facilities
f. Tractor maintenance facilities
g. POHSSC inflation, retrieval and cleaning equipment
h. POHSSC repair facility
i. Trailer loading and unloading cranes
j. Loading crane for sled

A major support requirement exists for storage space for the equipment. As calculated above, space is required for about 93 tractor/semi-trailer units or 307 trailer-launcher units. If all equipment is stored on trailer-launchers, then about 300 vehicles would be required, spread over 14 sites. This comes to an average

of 19 per site. Allowing 1000 square feet per vehicle gives an average of about 0.43 acre per site. Unfortunately the equipment is densest in harbors such as Philadelphia, New York, San Francisco and New Orleans where space is at a premium. The allocation of storage space and location appears to be an important problem that must be resolved on a site-by-site basis.

11.8.4 Staffing and Maintenance

The present Strike Teams consist of about 20 members. Typical equipment includes two to three barriers, four to six ADAPTS, and one tractor/semi-trailer. A major spill will undoubtedly involve other than USCG personnel trained in pollution response. The core requirement depends on tasks that cannot be delegated to personnel inexperienced in pollution control. The following estimates are made for trained personnel:

ADAPTS operation: 2 men per 8-hour shift, of which 1 is trained. This gives 3 trained men per pump. A large pumping operation may be sustained with one trained man per pump. This gives about 14 men minimum and 42 maximum.

OWOCS operation, excluding tow vessel personnel, is estimated to be 3 for deployment (an average of 1 per unit will probably suffice for sites with multiple units), plus at least one experienced operating man per shift. This is a total of about 5 per unit or 340 systemwide.

POHSSC operation is included in the OWOCS estimates above, but at least three men per site would be required to supervise deployment, retrieval, and transport of these units. Total: 48 throughout the system.

The above estimates for trained operating personnel may be summarized as follows for Configuration 5W (all sites, including Hawaii and Puerto Rico):

ADAPTS: 14 to 42
OWOCRS: Approximately 340

POHSSC: Approximately 48

These trained personnel would perform routine maintenance but a number of mechanics, technicians and/or contractor personnel would be required at each site for major repairs. No attempt is made to estimate these support personnel. In addition, communications specialists and logistics supervision would be required at each site. Finally, USCG officers would be required for over-all supervision and operation.

Considering that the operation personnel may be transported much more easily than the equipment itself, it may be possible to reduce the number of operating personnel system-wide by staffing only the larger sites and performing routine maintenance at other sites on a rotating basis. The major difficulty here, however, is obtaining enough trained operating personnel to man a massive spill operation, during which virtually all available equipment would be simultaneously employed. This may be handled by training USCG personnel, normally assigned to other duties, in the operation of the ADAPTS, POHSSC or OWOCS equipment. The requirements for such an approach to staffing were not investigated in this study, but the approach appears to offer substantial cost savings.

12. RESULTS AND CONCLUSIONS

The objective of this study has been to analyze US Coast Guard pollution response equipment requirements and to determine a set of strategically located equipment staging sites and associated equipment levels that would enable the Coast Guard to respond within six hours to major oil spills in US waters, including a possible massive spill as large as 100,000 tons. The results of the study and some of the conclusions that may be drawn from it are summarized below.

12.1 RESULTS

Non-Massive Spill Potential: (Section 3) A data base of spills over 50,000 gallons in US coastal waters was extracted from the Pollution Incident Reporting System and the National Response Center files, covering the years 1974 through 1977. It was found that:

1. The spill rate was relatively constant at about 20 per year.

2. About 55% of the spills and 65% of the spill volume occurred in the winter season (October through March)

3. The national average spill rate in 1974-77 was .0314 spills per million tons of oil throughput. The following estimates were made for different coastal regions and for different spill sources (Spills per million tons of throughput):

Greater NY	0.021
Delaware Bay	0.063
Louisiana Coast	0.068
N. Texas Coast	0.019
Transient Tankers	0.0003
OCS Production	0.036
Deepwater Ports	0.003

4. In the 1974-77 data that most spills were small, but most oil was spilled in large spills, verifying the results of other studies.

Massive Spill Potential: (Section 4) In order to establish scenarios for massive oil spills in US waters, 68 world-wide spills greater than one million gallons were examined,* as were potential changes in coastal oil movement and production in the 1980-1990 decade, with the following results:

1. Spills within 50 n. miles of the shore were predominantly groundings (24%), strandings (43%)collisions (19%), mechanical and structural failures (14%). These results are consistent with other studies.

2. Average outflow rates estimated for seven of the largest spills ranged from 50 tons per hour (METULA) to 600 tons per hour (AMOCO CADIZ).

3. Data on oil well blowouts show that the largest have been in the range of 5 to 140 tons per hour, with total volumes of from 7,000 tons to 40,000 tons.

4. Based on assumptions with regard to oil imports, Alaskan oil production and distribution, possible Deepwater ports, and future oil demand, the following coastal areas were found to have a relatively high potential for massive spills, and were selected for scenarios:

    - Pacific Northwest Coast
    - Straits of Florida

   A third area was added because of potential serious consequences of a spill:

    - Baltimore Canyon Trough OCS

Environmental Factors (Section 5): National Oceanic and Atmospheric Administration data yielded the following information:

1. Wave heights in US Coastal Waters exceed 5 feet from 25% to 75% of the time in February, and from 4% to 37% in August.

2. The average duration of seas less than 6 feet on the North East US Coast ranges from 40 to 83 hours in winter and from 117 to 315 hours in summer.

*The spills span the period 1967-1978, from the TORREY CANYON to the AMOCO CADIZ.

Equipment: (Section 6) The baseline equipments designated by the US Coast Guard for this study have the following gross characteristics when packaged complete for transport:

	POUNDS	CUBIC FEET	DOLLARS
ADAPTS	6,000	200	60,000
OWOCS/Skimmer	19,000	1,100	175,000
OWORS/Barrier	33,200	2,070	904,000
POHSSC Type OW	13,700	738	240,000
POHSSC Type F	8,800	342	90,000
POHSSC Type D	3,720	270	40,000

Logistics: (Section 7) Five delivery options were examined, with the following results:

1. Direct water transport, in which the equipment is stored in a towable vessel, either moored or on a launch ramp, provides more rapid response than land transport up to a distance of about 36 n. mi.

2. Land transport by pre-loaded tractor/semi-trailer can cover a range of about 140 n.mi. within a six hour time (from OSC request to arrival at debarkation point).

3. Helicopter delivery of equipment from storage site to debarkation point is inferior to land transport because of the limited range - payload combinations available with even the heaviest US made helicopters.

4. Fixed Wing Air/Land transport using C130's and tractor trailers is superior to land transport for ranges greater than about 100 n.mi., provided the estimated preparation, loading and unloading times are achieved.

5. Fixed Wing/Helicopter transport is inferior to Fixed Wing/Land in most cases.

A sixth possible transport mode (transfer waterborne) consists of a launchable towed vehicle that can be transported over land by a tractor. This mode, which has not been developed, appears to warrant investigation.

Site Locations (Section 8): Ten site configurations for non-massive spills were evaluated. The criteria were (a) percent of spill response times greater than six hours, and (b) average response time.

It was found that (Figure 8-14):

1. With regard to the first criterion, Configurations A through D, derived on the basis of geographic coverage of debarkation points, are superior. Of these four, configuration C is to be preferred.

2. With regard to the second criterion, Configurations 1 through 4, derived by collocating the sites with port areas of greatest spill potential, achieved lower average response times. In general, the average response time improved smoothly from 4 hours to 2 hours as the number of sites increased (Figure 8-14). But these configurations have about 5% of their spill response times greater than six hours, compared to about 2% for Configurations A through D.

3. The addition of a single air based equipment site in the eastern United States (e.g. Clearwater FL or Elizabeth City NC) to Configurations 1 through 4 dramatically reduces the percent of responses greater than six hours.

Based on the above evaluations, a composite configuration, with optional addition of air sites, was developed (See Configurations 5, 5a and 5b, Section 8).

Equipment Levels (Section 9): The relative and absolute levels of oil recovery capability for non-massive spills were established for Configurations 5, 5a, and 5b as follows:

1. Relative capability levels of the sites were established on the basis of maximizing the average amount of oil recovered per year, using a simple model for recovery capability with the spill volume and frequency distributions obtained in the spill potential study (Section 3). The results are contained in Tables 9-1 through 9-6.

2. Absolute capability levels for the sites were established by setting the average total annual recovery level at 80% of full recovery. This point corresponds to an overall equipment utilization of 10% per year. The resulting recovery capability is 40 million gallons for harbor recovery, plus 30 million for open water recovery.

3. Based on a set of assumptions on the duration of spills and the effectiveness of various equipments, the capability was estimated for non-USCG equipment, as contained in available inventories and lists. These capabilities were subtracted from the total capabilities calculated for the sites to obtain the net

required US Coast Guard capability at each site (Tables 9-9 and 9-10).

Massive Spill Response (Section 10): The response required by the three massive spill scenarios of Section 4 was evaluated (Table 10-5). Estimates were made of the pumping rates, skimming rates, and storage required to effect recovery of the oil under the assumed weather and geographic conditions for the three scenarios. It was found that

1. The equipment levels obtained in Section 9 were more than adequate to cope with any one of the three massive spills postulated, provided (a) the equipment could be delivered to the spill in a timely manner, and (b) the equipment performed according to its nominal specifications.

2. The site configuration employed need not be modified to meet the assumed massive spills.

Three logistic strategies were tested for massive spill response: All-land, land collection to regional airports, land collection to local airports. It was found that:

1. All-land transport provided adequate response to the massive spills tested on the Gulf and East coasts.

2. The second and third strategies (air delivery) require from 16 to 36 USAF C141 aircraft to provide good response. The selection of airports was not as critical as the disposition of C141 aircraft.

Recommended Deployment (Section 11): A recommended system deployment was synthesized from the site configuration developed in Section 8, the equipment levels of Section 9, and the massive spill requirements of Section 10. The other factors taken into account were:

1. The possibility of combining open water and harbor recovery requirements.

2. The possibility of combining land-based with water-based equipment requirements.

3. Assistance from site to site.

4. Air delivered capability.

5. Maximum non-massive spill assumed.

When the above factors were taken into account it was found that a slight modification of Configuration 5, with a total US recovery capability of 15 million gallons, can meet an 80% recovery percentage as well as the requirements developed for massive spill response. The capability levels for the sites are given in Table 11-9, and the total units of equipment are given in Table 11-11.

12.2 OBSERVATIONS

The following observations have to do with the critical procedures of this study. A procedure is called "critical" if it is both influential in the results and not well established. Among those contained in this study, the following deserve recognition:

1. The calculation of spill potential from (among other things) oil movement. The difficulty here is that oil movement is well recorded only for ports, channels, and other waterways. The estimation of coastal traffic and corresponding spill potential must proceed on the basis of the coastal and foreign component of port oil movements, and/or on approximate flow information, such as referenced in Sections 3 and 4. In either case little information is obtainable about the location of critical points along the coast. Knowledge of coastal traffic could alter the optimum location of sites.

2. The use of average values for response intervals. Assuming the values employed are the mean values, one still must deal with the effect on the results of the variance of these estimated means. Examples are the values employed for notification and alert time, loading times, and travel speeds (except for aircraft).

3. The use of the simplified recovery model of Appendix K, which assumes 100% oil recovery up to the limit of the site's capability. The inaccuracy arises not because 100% recovery is never achieved (a lesser percentage would not alter the results), but because recovery effectiveness varies widely with conditions other than equipment limits, such as weather, oil type and local coastal geography. In so far as these factors vary from site to

site, the results of optimizing on the basis of the recovery model will be in error. A case in point are the weather conditions which, as seen in Section 5, vary by about ± 25% on the average from Maine to Washington state.

4. The assumption that a buoy tender or crane is available at the debarkation point. This assumption affects the total time to a spill for Land and Air/Land options (tractor/semi-trailer) but not for the Direct Waterborne option. It also affects the time to a spill for Transfer Waterborne when the equipment site is not at the debarkation point.

5. The use of nominal performance figures for the baseline system elements. Pumping rates vary with viscosity, and what may be adequate for the "average crude" oil may be inadequate for No. 6 at the same temperature. Skimming rates vary with slick thickness and sea state, as well as viscosity. The amount recovered will differ, perhaps by a factor of 5 or 10, from the nominal amounts under some sea states and viscosity conditions. Perhaps the greatest uncertainty arises in the assumption that towing and maneuvering of either OWORS/Barrier or OWOCRS can be carried out under realistic conditions using available vessels, so as to yield the nominal 300 gpm skimming rates. Actual experience in slick recovery using the barrier sweeping method is sparse and does not include the operation of this technique with the POHSSC attached. The results of the massive spill study are contingent upon the possibility that such an operation can be carried out successfully.

6. The use of approximations such as Figure 10-4 for slick size. Skimming effectiveness depends on the average slick thickness, which is a function of the total area covered by the slick. This is true even when thick pancakes have formed since they will be separated by large spaces on which the slick is very thin. For this reason skimming performance is strongly affected by the values assumed for the area covered by a slick.

7. With regard to massive spill response, several procedures and assumptions should be noted as critical: The number and availability of C141 aircraft and loaders have not been fully established in this study. The same applies to leased tractor-trailers.

8. Performance characteristics of non-USCG equipment. The inventory information available at the time this report was prepared had not yet been checked for accuracy and completeness. In addition, the capabilities assigned or calculated for the different equipments depend upon assumptions about, rather than actual specifications for each piece of equipment. When a refined data base is available, changes in the USCG equipment requirements can be expected.

12.3 CONCLUSIONS

From the results and observations above, several conclusions may be drawn. These fall into four general categories, corresponding to the four questions posed at the beginning of the report (Section 1.2):

1. Where should pollution response equipment be located?
2. How much equipment should be stored at these sites?
3. How effectively can it deal with a massive (100,000 ton) spill?
4. What will it cost to purchase and maintain?

Location

The equipment should be sited according to Configuration 5W. This configuration allows delivery of the equipment to the spill debarkation point within six hours of receipt of the OCS' request, for over 90% of the spills anticipated in US coastal waters (Alaska excluded) in the next decade. For the most part, delivery can be effected by tractor-trailer, or towed water sled; but development of a combined trailer-launcher should be investigated. The response intervals (alert time, loading, travel, unloading, etc.) required to meet the 6-hour delivery are believed to be

achievable by US Coast Guard personnel adequately prepared and specifically trained for the pollution response mission.

Levels

The level of recovery capability recommended for each site is given in Table 11-9. This table gives recommended pumping, storage, skimming and containment capability (in thousands of gallons). The total US capability, as given in the Table, is 15 million gallons. It will yield 80% recovery based on certain assumptions: (1) the open-water and harbor capabilities are consolidated, (2) the land-based capability is combined with the water-based capability, (3) 50% assistance is available from adjacent sites.

Converting the required capability in gallons to units of baseline equipment requires certain assumptions, given in Table 9-13, regarding offloading start and stop time, arrival of relief barges, skimming efficiency, and hours of operation per day. When the total US capacity is converted to baseline units the results are approximately 14 ADAPTS, 18 Type OW barges, 68 OWOCRS, and 254 Type F barges, as shown in Table 11-10. Actual numbers of units at each site will depend on rounding to integral numbers of units and spares for maintenance.

Massive Spill Effectiveness

The totals of equipment recommended for Configuration 5W are, in general, adequate to meet the requirements of any one of the three massive spill scenarios. The major difference occurs in the number of Type OW POHSSC, which should be increased from 18 to 42 to meet, approximately, the requirements of Scenario A. This will produce an approximate equivalence between the total amount of equipment available for the US sites to that required to meet a massive spill, as depicted in the selected scenarios. Whether the recommended deployment will be effective in actual recovery of oil from a massive spill, however, also depends on factors other than this equivalence, all of which militate against an effective recovery operation. These factors are:

1. Logistics: Transport of the total complement of equipment from the 14 sites scattered over the US to and from the Pacific Coast, Hawaii and Puerto Rico would require substantial air lift assistance. A plan for such assistance needs to be worked out.

2. Weather: The results of Section 5 show that wave heights exceed 5 ft (the operating nominal limit of the baseline boom) about 50% of the time in February, and about 20% of the time in August. Thus the chances of carrying out a successful skimming operation off the US coast at any one time may be reduced by about 20% to 50% because of weather alone.

3. Equipment State of the Art: While equipment performance is fairly well established for the ADAPTS and OWOCS, the other elements of the Baseline system are newer, and data are still being collected on their performance and operating characteristics under realistic conditions. The completion of unit testing, and, in particular, of total system integration tests of the OWOCRS/Type F barge must be awaited before its real capability in adverse weather conditions is known. Success of a massive spill recovery depends on the performance of these baseline elements, and the development of appropriate operating procedures.

Of these factors, the first is the easiest to overcome, since the required capability exists and needs only to be integrated into present contingency plans. The third factor is somewhat more difficult to mitigate, depending on continual improvements in the state of the art. The second factor, however, promises to pose formidable design difficulties for several years before the present nominal performance limits of 5 ft. waves and 20-30 knot winds can be raised significantly.

Cost

The very brief cost analysis made in Section 11.8 can serve

only to provide an order-of-magnitude estimate. The analysis shows about $50 million in equipment purchase costs, about $10 million in vehicle purchase costs (based on a trailer-launcher). Support equipment costs can be expected to add an additional $10-20 million. The cost of land acquisition must be added to this, as well as cost of development and research, and testing. Allowing $10 million for these items brings the total capital outlay for the recommended deployment to the range of $80 million to $100 million, with a nominal amount of $90 million. It should also be realized that developmental efforts may produce equipment superior to the baseline that was employed in this analysis, which could modify the purchase costs. To the capital outlay one must add recurring costs. These have not been estimated, but were discussed in Section 11.8.4. Finally, it should be noted that all costs have been quoted in 1976 dollars and should be adjusted to the actual date of purchase, when known.

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